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U. S. TORPEDO-BOAT DESTROYERS *BAINBRIDGE, BARRY* AND *CHAUNCEY.*

By JAS. NELSON ALEXANDER.

The *Bainbridge, Barry* and *Chauncey* are twin-screw torpedo-boat destroyers of 420 tons displacement, and were built by the Neafie and Levy S. & E. B. Co., of Philadelphia, Pa. The general plans and specifications were furnished by the Navy Department, but the development of details and arrangement and location of auxiliary machinery and piping were made by the contractors. All drawings, however, were submitted to the Navy Department for approval before the work was begun.

The contracts for these three vessels were signed October 1st, 1898, the price being $283,000 each, and the time allowed for completion eighteen months. The price of $283,000 is exclusive of ordnance and ordnance outfit, which is furnished by the Government.

An extension of time for completion of seventeen, eighteen and nineteen months, respectively, was allowed for the *Bainbridge, Barry* and *Chauncey*, primarily because of the difficulty

experienced in the delivery of material for use in their construction.

The speed guaranteed was twenty-nine knots per hour, to be maintained successfully for two consecutive hours. This clause in the contract was afterward modified by the Navy Department to read "Standardization runs to be made up to the highest attainable speed of the vessel; these not to be considered satisfactory unless a speed of twenty-eight knots is reached for all destroyers. After the standardization trials, the destroyers to make a satisfactory run of one hour at an average speed of at least twenty-six knots per hour." The above requirements to apply to speed alone, and not to operate to change or modify the many other requirements of the vessels for acceptance.

The weight of machinery was limited to 198 tons, not to include stores and spare parts supplied by the Government, steam steering gear, steam windlass, dynamo engine and torpedo air-compressing machinery. The penalty for overweight of machinery was $200 per ton over 198 tons, and if this overweight exceeded 5 per cent. of the contract weight, then $1,000 additional was to be deducted from the contract price of the vessel.

HULL.

The hull is constructed of mild steel of domestic manufacture, with frames spaced 21 inches apart. The flat keel plates are of one thickness of plate, 12½ pounds per square foot, for two-thirds the length amidships; forward and abaft this length it is reduced to 10 pounds per square foot. The vertical keel is 10 pounds per square foot, extending above floor plates, with double angles at top and bottom edges, 2 by 2 inches by 2½ pounds. The outside plating for sheer strake is nickel-steel of 12½ pounds per square foot for two-thirds the length amidship, reduced to 10 pounds per square foot at the ends. All other shell plating of 9 pounds per square foot for two-thirds of the length amidships, reduced to 7 pounds per square foot at the ends, except the garboard strakes, which is 10 pounds amidships, reduced to 8 pounds at ends. Seams are lapped and double riveted for two-thirds length amidships; single riveted at

ends. Butts of sheer strake are single strapped and treble riveted for two-thirds the length amidships; the butts of the remainder of the plating are double riveted. The whole of the outside plating under water and to one foot above normal water line, the floor plates, bulkhead plates, reverse frames and frames to one foot above normal water line, vertical plates, and bilge keels are galvanized by the hot process.

In all there are thirty-one watertight compartments, including coal bunkers and compartments that are subdivided. There are eight coal bunkers, located on each side of engine and boiler rooms, having a total capacity of 180 tons at 43.5 cubic feet to the ton. Thirty-two tons of coal, extra, can be stored in bags in reserve feed-tank compartment forward of bulkhead No. 35, underneath the crew's quarters.

The crew's quarters are located in the forward part of the vessel, and the officers' quarters at the stern, while the chief petty officers' and petty officers' are just forward of the officers' quarters on the starboard and port sides, respectively. Accommodations are provided for 4 officers and 69 crew. The living spaces are heated by steam heat.

There are two conning towers, one located forward and the other aft. The forward tower is made of nickel-steel plates $\frac{1}{2}$ inch thick; the after tower is of steel plates $\frac{1}{4}$ inch thick. Steam and hand-steering wheels and binnacles are located in the forward conning tower, while in the after tower is located a hand-steering wheel and a steering compass.

A change in the after body of the *Bainbridge*, *Barry* and *Chauncey* was made before these vessels were launched. The change consisted in altering eleven frames of the stern to get rid of a hook in the after body.

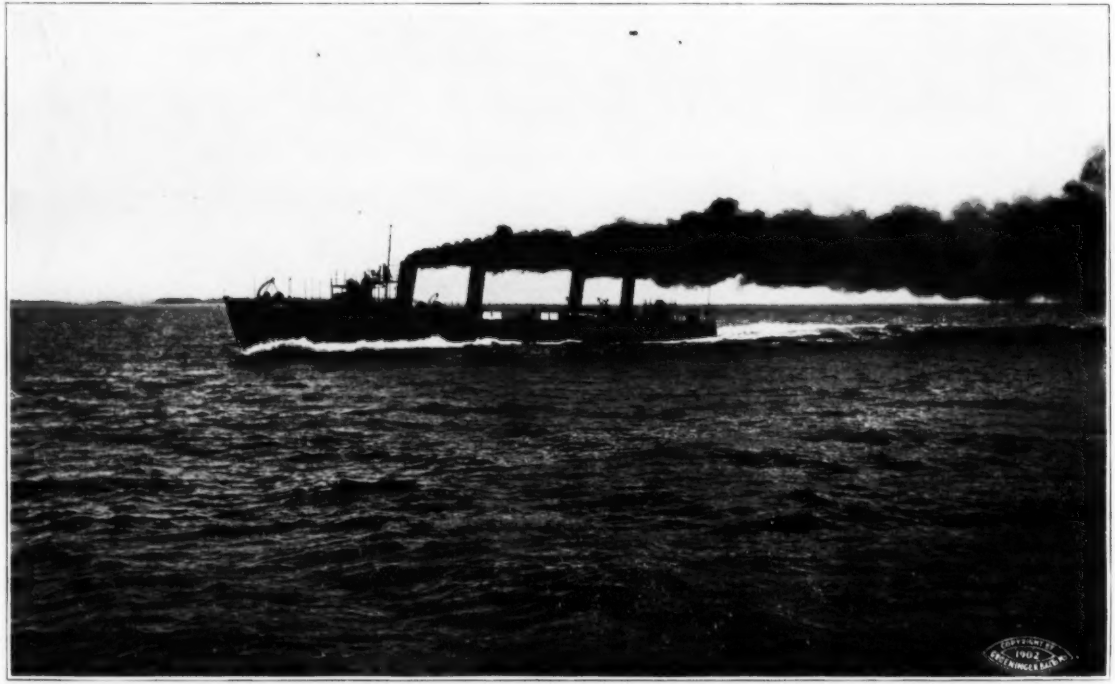
The battery consists of two 3-inch 50-caliber rifles, five 6-pounder semi-automatic rapid-fire guns, two Whitehead C. P. torpedo tubes, the air compressor for which is of the Rand type V. Two torpedoes are carried in the tubes and two stored.

Two 20-foot cutters, two 20-foot whale boats and one 16-foot dinghy are carried on deck.

HULL DATA (CHAUNCEY).

Length between perpendiculars, feet and inches	244- 2⅞
Length on L.W.L. (6 feet 6 inches normal L.W.L.), feet and inches	240- 6¼
Length over all, feet and inches	249- 9⅞
Beam, extreme, feet and inches	23- 5
Beam at L.W.L. (6 feet 6 inches normal L.W.L.), feet and inches	23- 0½
Depth amidships from keel to crown of beam, feet and inches	14-11¾
Molded depth at side, feet and inches	14- 2⅞
Average draught of hull on trial, forward, feet and inches	5- 6
aft, feet and inches	8- 8¾
mean, feet and inches	7- 1⅝
Mean displacement on trial, tons	460.8
Tons per inch immersion	9.60
Area of immersed midship section, square feet	112.5
Center of gravity of L.W.L. plane aft of midship section, feet and inches	5- 0
Center of buoyancy, forward midship section, feet and inches	4- 3
above base, feet and inches	4- 5¼
Transverse metacenter above center of buoyancy, feet and inches	8- 9¾
Block coefficient for displacement	.43
Midship section coefficient	.703
Wetted surface, square feet	6,170

Drainage System.—The main drain pipe is of galvanized steel and extends fore and aft with branches to the bilges in each compartment, excepting one compartment forward and two end compartments aft. These end compartments are drained by sluice valves into the compartments next to them. The main drain pipe is 3 inches in diameter between the forward branch in the forward boiler compartment and the after branch in the after boiler compartment, with 3-inch branches to the bilges in the engine and boiler compartments. Beyond the drain branches in the boiler compartments the main drain is 2 inches in diameter, with branches 2 inches in diameter at the lowest point in each compartment. The main drain is connected to the fire and bilge pumps in each engine room. A hand pump, located on deck, is connected to the main drain pipe, so that each compartment can be pumped out when there is no steam on boilers. For the purpose of disposing of large volumes of water in engine and boiler rooms there is an auxiliary drain pipe, with branches leading to



U. S. DESTROYER "BAINBRIDGE" AT FULL SPEED.

bilges in these compartments. This pipe is 7 inches in diameter and is connected with the centrifugal circulating pumps in engine rooms.

MAIN ENGINES.

There are two vertical, inverted, direct-acting, triple-expansion, four-cylinder engines, placed in separate watertight compartments, the starboard forward, and the port aft, with a transverse bulkhead between. The engines were designed for 8,000 H.P. when making 327 revolutions per minute. The arrangement of cylinders is as follows, beginning forward: For the starboard engine, 2d L.P., I.P., H.P. and 1st L.P.; for the port engine, the order is reversed, reading, 1st L.P., H.P., I.P. and 2d L.P.

The cylinders are supported by twelve forged-steel columns, $3\frac{1}{8}$ inches in diameter. The horizontal stresses are taken by diagonal braces secured at top to lugs on bottom of steam cylinders, and to lugs on crankshaft bearings at bottom. The columns are stiffened by fore-and-aft horizontal and diagonal athwartship tie bars, all of forged steel. At the back of the engine a strongback of cast steel is bolted to columns, acting in a double capacity of stiffeners for columns and a support for lower end of crosshead guides. The main valves are all piston valves, double ported, there being one valve for each high-pressure cylinder, two for each intermediate and low-pressure cylinders. Each valve has two heads or pistons, the top one being slightly larger in diameter for balancing purposes. This arrangement does away with the balance cylinders on top of the valve chests, the usual method of taking the weights of the valve gear off the eccentrics. All valves are worked by Stephenson double-bar link motion and have adjustable cut offs actuated by screws in slotted arms of the reverse shafts.

The eccentrics are of cast iron and keyed to the crank shafts. The eccentric straps are of composition lined with the Government standard babbitt metal, and the eccentric rods are of forged nickel-steel. The steam pistons are of the dished type, and for the intermediate and low-pressure cylinders are steel forgings, while the high-pressure piston is made of cast iron of

U. S. DESTROYER "BAINBRIDGE" AT FULL SPEED.

heavy section to make weights of reciprocating parts the same for all cylinders. The piston packing rings are cast iron sprung into grooves turned in the periphery of the pistons. The weights of reciprocating parts running opposite are accurately balanced. The finished parts varied but slightly in weight, and the difference was made up by screwing composition plugs in the axial holes in piston end of piston rods. The piston rods are of forged nickel-steel, with crossheads forged on, and a bored axial hole running the whole length of the rod. The crosshead slippers are of phosphor-bronze, lined on the ahead side with babbitt metal. The connecting rods are of hollow-forged nickel-steel, with forked ends to span the crossheads, and crosshead pins shrunk in. The crank-pin end of each rod is fitted with shell brasses lined with babbitt metal. The crosshead guides are of cast iron and made hollow for circulation of water to keep them cool. At the top they are bolted to lugs on the steam cylinders, and at the bottom to cast-steel strong backs bolted to engine columns. The backing guides are of cast steel bolted to go-ahead guides. The crank-shaft bearings are steel castings, of I section bolted directly to engine keelsons.

There is an 8-inch balanced throttle valve to each engine, operated by a lever from the working platform. On each throttle valve is a 1½-inch by-pass valve for slow running and warming up.

All the crank, line, thrust and propeller shafts are forged steel with holes drilled axially through them. The crank shafts are made in two sections, with two cranks on each section, placed opposite each other. The cranks of the high and first low-pressure cylinders are opposite each other, and the intermediate and second low-pressure cranks are similarly placed in regard to each other. The high and first low-pressure cranks are at right angles with the intermediate and second low-pressure cranks, the sequence being H.P., I.P., 1st L.P. and 2d L.P. The thrust shafts bolt to the after end of each crank shaft and have eleven thrust collars, 12 inches outside diameter. The stern-tube shafts, between bearings in stern tube, are covered with a drawn-brass pipe ⅛ inch in thickness. The thrust bearings and caps are of

manganese-bronze and pedestals of cast steel. The bearings and caps are cast hollow, with three pockets, the middle one forming an oil trough, the outer ones fitted for water circulation. The collar spaces of bearings and caps are lined with babbitt metal channelled for the distribution of oil. The propeller shafts are each supported by two outboard strut bearings, the stern-tube shafts by bearings at each end of stern tubes, the starboard line shaft by two, and the port line shaft by one spring bearing. The bearings for stern tube and propeller shafts are lined with lignum vitae, end grain exposed, while the spring bearings are lined with babbitt metal in lower half of bearing only.

The reversing gear for each engine consists of a steam cylinder and an oil cylinder to act as a dash pot, acting on arms fixed on the reversing shaft by means of connecting links. The valve of this engine is worked by a system of differential levers, the primary motion being derived from the hand lever on the working platform, and the secondary motion from a pin on the crosshead of the reversing engine.

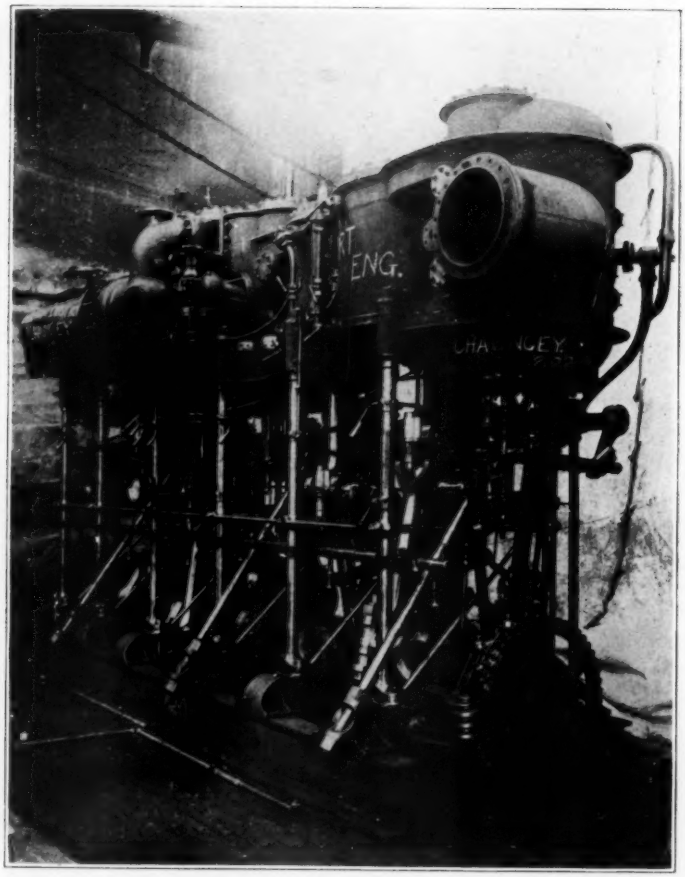
The turning gear consists of a worm wheel on the forward end of each crank shaft worked by a worm and hand ratchet.

ENGINE DATA.

Cylinders, number for each engine	4
H.P., diameter, inches	20½
I.P., diameter, inches	32
L.P. (two), diameter, inches	38
Stroke, inches	22
Valves, H.P. (one for each cylinder), diameter, inches	12
I.P. (two for each cylinder), diameter, inches	12
L.P. (two for each cylinder), diameter, inches	13
Valve stems (for all valves), diameter, inches	1¾
Main steam pipe, diameter, inches	8
exhaust pipe to condenser (two), diameter, inches	16
Piston rods, diameter, inches	4¼
axial hole, diameter, inches	2¾
length from piston to center of crosshead pin, inches	45
Connecting rods, section at upper end, diameter, inches	3⅞
section at lower end, diameter, inches	4⅝
axial hole, diameter, inches	2¼
center to center, inches	46⅝
Crank-pin bolts (two), diameter, inches	2½

Crosshead pins, diameter, inches	5¼
length, inches	8½
axial hole, diameter, inches	2½
Crossheads, wearing surface, ahead, inches	12 × 16
backing (two), inches	2½ × 16
Crank shaft, diameter, inches	8½
axial hole, diameter, inches	4¾
coupling flange, diameter, inches	15¼
thickness, inches	2
shaft, coupling bolts (eight), diameter, inches	1 1/16
journals, diameter, inches	8½
(four), length, inches	9½
(two), length, inches	12
(one), length, inches	14
pins, diameter, inches	8½
length, inches	12
webs, width, inches	10½
thickness, inches	4½
Thrust shaft, diameter, inches	7⅞
coupling flange, diameter, inches	15¼
axial hole, diameter, inches	4¾
collars, number, each shaft	11
diameter, inches	12
thickness, inch	1
space between, inches	1½
length, feet and inches	4– 2
Line shafts, port (one), diameter, inches	7⅞
axial hole, diameter, inches	4¾
length, feet and inches	15– 6
starboard (two), diameter, inches	7⅞
axial hole, diameter, inches	4¾
combined length, feet and inches	40– 1
Stern-tube shaft, diameter, inches	7⅞
axial hole, diameter, inches	4¾
length, feet and inches	36– 1½
Propeller shaft, diameter, inches	7⅞
axial hole, diameter, inches	4¾
length, feet and inches	

Screw Propellers.—The propellers have each three blades, are true screw, and made of manganese-bronze, with blades cast on hub and tinned all over. The starboard propeller is left-handed and port propeller right-handed, which will make the top blades turn inboard when going ahead. This is done in order to allow the crosshead guides to be bolted on the outboard columns of the



TYPE ENGINE OF DESTROYERS "BAINBRIDGE," "BARRY" AND "CHAUNCEY."

engines and have everything clear on the working platform side. Each propeller is secured to its shaft by two feather keys, placed opposite each other, and a nut screwed on and locked in place.

Number of blades	3
Diameter, feet and inches	8– 0
Length of hub, inches	21
Diameter of hub, inches	17
Mean pitch as set for *Bainbridge*, feet	10.609
Barry, feet	11.255
Chauncey, feet	11.073
Helicoidal area, each screw, square feet	24.9
Projected area, square feet	20
Disc area, square feet	48.6
Pitch ÷ diameter *Bainbridge*	1.326
Barry	1.4
Chauncey	1.384
Helicoidal area ÷ disc area	.51
Projected area ÷ disc area	.41

Main Condensers.—There are two main condensers, one for each engine. The shells are of copper, No. 7 B.W.G. in thickness, made in three flanged cylindrical sections bolted together with T-ring stiffeners of composition between sections. The water chests are copper with tube sheets of Muntz metal. Zinc protectors are fitted in water chests, and deflecting cones in inlet chest to distribute the circulating water evenly through all tubes. The circulating water is delivered by a scoop when the vessel is under way, but when at a standstill the water is supplied by a small centrifugal circulating pump.

Diameter of shell, inside, inches	$51\frac{3}{16}$
Thickness of shell	No. 7 B.W.G.
Tubes, diameter, inch	$\frac{5}{8}$
length between tube sheets, feet and inches	9– 3
thickness	No. 20 B.W.G.
number in one condenser	2,292
Cooling surface, each condenser, square feet	3,470
total, square feet	6,940
Ratio, total cooling to total heating surface	1 to 2.56

Air Pumps.—There are two double-acting, vertical, Bailey air pumps for each engine, worked from the high and intermediate-pressure crossheads. Diameter of each pump piston is 12 inches

and stroke 6 inches. The pump valves are each made of three flat discs of rolled manganese-bronze $\frac{1}{32}$ inch thick.

Circulating Pumps.—For each condenser there is one single inlet, water-balanced, centrifugal circulating pump, driven by a vertical single-cylinder engine, with cylinder $4\frac{1}{2}$ inches diameter and 5-inch stroke. The pump runner is 20 inches in diameter, and the width of runner at periphery $1\frac{1}{4}$ inches. The inlet and outlet nozzles are both 7 inches in diameter. Besides being connected to draw from the sea, it is connected to pump from the bilge, and is capable of delivering 2,000 gallons per minute from the bilge.

BOILERS.

There are four "Daring" type of Thornycroft water-tube boilers, with a total grate surface of 315 square feet and a total heating surface of 17,768 square feet, and built for a working pressure of 300 pounds per square inch. The boilers are placed fore and aft in water-tight compartments, two being located forward of the forward engine room, and two aft of the after engine room.

In this type of Thornycroft boiler there is one steam drum, located at the apex of an isosceles triangle, a water drum at the middle of the base, and two smaller water drums at the lower angles of the triangle.

The steam drum is connected to each of the water drums by $1\frac{1}{8}$-inch and $1\frac{1}{4}$-inch solid-drawn steel steam-generating tubes 11 B.W.G. in thickness. The steam drum is also connected to the center water drum by fourteen 4-inch downtake tubes. The feed water is fed into the steam drum, dropping down through the downtake tubes to the center water drum, thence to the wing drums through connecting pipes at the back of the boiler, and filling the generating tubes. The upper ends of the generating tubes in the steam drum are never submerged, the water level being below the lowest row of tubes. The tubes are expanded into the drums with about $\frac{5}{16}$ of an inch of each tube projecting into the drums, and are bell-mouthed to an angle of about 25 degrees, with a tool similar in construction to the tool expanders used in expanding the tubes in the drums. This method of securing the tubes makes it almost impossible for a tube to pull out.

Incidently, I will say to the credit of the builders that not one of the 20,616 tubes in the twelve boilers for the *Bainbridge, Barry* and *Chauncey*, after numerous trials, has shown evidence of a leak.

There are two furnaces to a boiler and two doors to a furnace. The grate bars are of wrought steel, in nests of six bars each. The backs and fronts of the furnaces are built up to the arch of the tubes with fire brick, and on each side to bottom rows of tubes in water drums. The boilers are covered with a casing consisting of ½-inch asbestos board placed between two thicknesses of galvanized-steel plates, the inside plates being No. 16 B.W.G. and the outside plates No. 20 B.W.G. in thickness. The covering is made in easily removable sections held together with light galvanized-steel angles. In the steam drums are fitted baffle plates, zincs, dry pipe and automatic feed-regulating gear. The automatic feed-regulating gear is the Thornycroft type. In the trials of these vessels it has not been in much use, for no one seemed to be willing to trust it, but preferred rather to depend on a good water tender. The small amount of water carried in this type of boiler, with the short length of time it takes to convert it into steam, necessitates a positive assurance that enough water is being fed to the boilers, and for this reason a Scotch engineer tersely expressed it in saying, "He would rather trust to the good judgment of a little 'mon,' the water tender, than to any automatic feed-regulating device." One 3½-inch duplex Crosby pop safety valve is fitted to each steam drum.

To each boiler is fitted a 5¾-inch combination-reducing-non-return-automatic-emergency-and-hand-steam stop valve for main steam line, and to it is bolted a 3½-inch valve of the same type for the auxiliary steam line. The automatic closing of these valves in case of a break in the steam line or accident to the boiler, which would permit a drop in steam pressure, with the arrangement to close all stop valves on boilers simultaneously, by opening a ¼-inch valve in engine rooms, in fire rooms or from stations on deck, is an ingenious but very complicated system. In this arrangement there is an auxiliary or pilot valve for each main and auxiliary stop valve on boilers, bolted to the

front of each boiler. About 550 feet of ¼-inch copper pipe is necessary to connect these pilot valves to their respective stop valves and to the stations in engine rooms and on deck, most of which is exposed and liable to be broken by the handling of firing tools in fire rooms or by accident while working around the engines. Such an accident to the line running to the stations would instantly close all stop valves on boilers, or an accident to any other of the piping would, of course, render the system inoperative.

On one of the builders' trial of the *Bainbridge* the pilot valve in this system on one of the boilers closed from some unknown cause and shut steam off from the boiler.

At the center of each furnace, above the doors, is fitted a spray nozzle for putting out fires by spraying water into the furnaces. Water for this purpose is furnished by the fire and bilge pumps in engine room.

There are four smoke pipes, one for each boiler, oval in section, having an area of one-seventh of the grate surface. The height of each smoke pipe is 28 feet above the grate.

In each fire room there is a hydraulic ash ejector.

Forced Draft.—The closed fire-room system of forced draft is used. The air is supplied by four Sturtevant blowers, two in the forward and two in the after fire room. The fans are driven by double, horizontal, enclosed engines; diameter of cylinders 5 inches, by 4 inches stroke. The diameter of fans is 54 inches.

BOILER DATA.

Steam pressure, designed, pounds	300
at engine, pounds	250
Number of boilers	4
Steam drum, length, feet	12
diameter, inside, inches	37
thickness, inch	1
Water drum, middle, length, feet and inches	10– 9
diameter, inside, inches	19
thickness, inch	⅝
wings, length, feet and inches	10– 9
diameter, inside, inches	7½
thickness, inch	½
Width over casing, three after boilers, feet and inches	15– 6

Width over casing, one forward boiler, feet and inches	14- 6
Height, feet and inches	10- 4
Furnaces, width grate, three after boilers, feet and inches	5- 9
one forward boiler, feet and inches	5- 3
length of grate, feet	7
Number of furnace doors	4
Tubes, diameter, inches	1¾ and 1¼
number, 1¾ inch	1,346
1¼ inch	372
thickness	No. 11 B.W.G.
Heating surface, tubes, four boilers, square feet	17,768
Grate surface, four boilers, square feet	315
Ratio H.S. to G.S.	56.4 to 1
Smoke pipes, four oval, feet and inches	2-6½ × 4-8
total area, four pipes, square feet	41.88
Ratio smoke pipe area to G.S.	1 to 7.52
Height of smoke pipe above grate, feet	28

Feed-Water Heaters. — In each engine room is a feed-water heater, which is similar in construction to a condenser. Each has about 200 square feet of heating surface and is located between the feed pumps and the feed mains. The feed water may, however, be by-passed around the heaters. Exhaust steam is the heating agent.

Evaporating and Distilling Plant.—The evaporating and distilling plant consists of two evaporators and one distiller, all of the straight-tube type; one distiller circulating pump and an evaporator feed and brine pump. The combined capacity of the evaporators is 3,000 gallons of water evaporated in twenty-four hours. The distiller has a capacity of 200 gallons of potable water at 90 degrees Fahrenheit per twenty-four hours.

Steam Ejectors—A steam ejector of 2,000 gallons capacity per hour is fitted in each engine and fire room for pumping out the bilges.

Mechanical Telegraphs and Revolution Indicators.—Mechanical repeating telegraphs are fitted in each engine room connected to transmitters in conning towers and on bridge. A mechanical signal system is fitted between each engine room and its adjacent fire room, and also between the engine rooms. Mechanical revolution indicators are fitted in each engine room, worked from the

engines by positive motion, and so arranged that the relative speed of both engines can be seen on the same dial at a glance.

Mechanical tell-tales were fitted in conning towers and on bridge, showing the direction of the revolution of the main engines, but failed to work satisfactorily at high speeds, owing to the jamming of the large number of bevel gears used, so was removed by direction of the Bureau of Steam Engineering.

Feed Pumps.—There are four main and two auxiliary feed pumps of the Blake vertical, single-cylinder type, all of the same size, 10 inches by 6 inches by 12 inches. The main feed pumps are located one in each engine room and one in each fire room. The pumps in engine rooms draw from the feed and reserve-feed tanks and air-pump channel ways, and deliver into the main and auxiliary-feed mains and feed tanks. The pumps in fire rooms draw from the feed and reserve-feed tanks and deliver into the main feed pipe.

The auxiliary feed pumps are located, one in each fire room, and draw from the feed and reserve-feed tanks, the sea and the boilers, and deliver into the auxiliary-feed mains, the fire main, the ash ejectors and overboard.

Fire and Bilge Pumps.—A fire and bilge pump of the Blake vertical, single-cylinder type, 8 inches by 6 inches by 12 inches, is located in each engine room, arranged to draw from the sea and the bilge, and to deliver into fire mains, overboard and into pipes for putting out the fires in the boilers.

Feed Tanks.—A feed tank of 213 gallons capacity is located in each engine room. A part of each tank is fitted as a filter, through which the water discharged by the air pump passes. The feed-pump suction at tank is provided with a balanced valve operated by a copper float in the tank worked by a lever outside the tank.

Reserve-Feed and Fresh-Water Tanks.—Reserve-feed tanks of a total capacity of 2,500 gallons are located forward of the forward fire-room bulkhead and aft of the after fire-room bulkhead. Fresh-water tanks of a total capacity of 1,200 gallons are located between frames 12 and 15 forward and between 106 and 109 aft.

Steering Engine.—On the floor of the forward conning tower

is a Williamson Bros., combined hand and steam-steering engine of horizontal type, with two steam cylinders 4½ inches in diameter by 4¼-inch stroke. There is a steering wheel on the engine, and one above it on the bridge. A ⅜-inch wire rope connects the quadrant on the rudder with the steering engine in the forward conning tower and also with the hand-steering gear in the after conning tower.

Steam Windlass.—A steam windlass, built by the Hyde Windlass Company, is located on the platform deck, between frames 8 and 11. The engine is of the reversible, double-cylinder type, with cylinders 4½ inches in diameter and 4½ inches stroke, and connects with the drums by worm and worm wheel. The two drums have each a capacity of 75 fathoms of wire cable, 2¾ inches in circumference. A capstan is located on the forecastle deck directly above the steam windlass and connected to it by means of a vertical shaft and bevel gears, with disengaging gear at windlass when using capstan bars.

Electric Plant.—The installation consists in general of one 5-kilowatt generating set, 100 incandescent lights, one searchlight, one main switch board, together with the necessary wiring and fixtures.

The generating set was furnished by the B. F. Sturtevant Co., and consists of a Shepherd engine and Sturtevant dynamo secured to a common bedplate.

The dynamo is the compound-wound, multipolar type, direct connected with the engine, and designed for 80 volts and 62½ ampères, with a speed of 730 revolutions per minute. The dynamo engine is an enclosed 2-cylinder, vertical type; diameter of cylinders, 3½ inches by 2½ inches stroke, designed to run under full load at 730 revolutions per minute with 100 pounds steam pressure.

The incandescent lights are 5 and 16-candlepower, designed for a potential of 80 volts. The vessels are wired on the two-wire system.

The switch board is equipped with one main dynamo switch and five circuit switches, two voltmeters, two ammeters, together with the usual rheostats, pilot lamps and ground detectors.

There is one Navy-standard 18-inch hand-controlled searchlight projector, made by the General Electric Company, installed on a special platform on forward bridge.

TRIALS OF THE *BAINBRIDGE.*

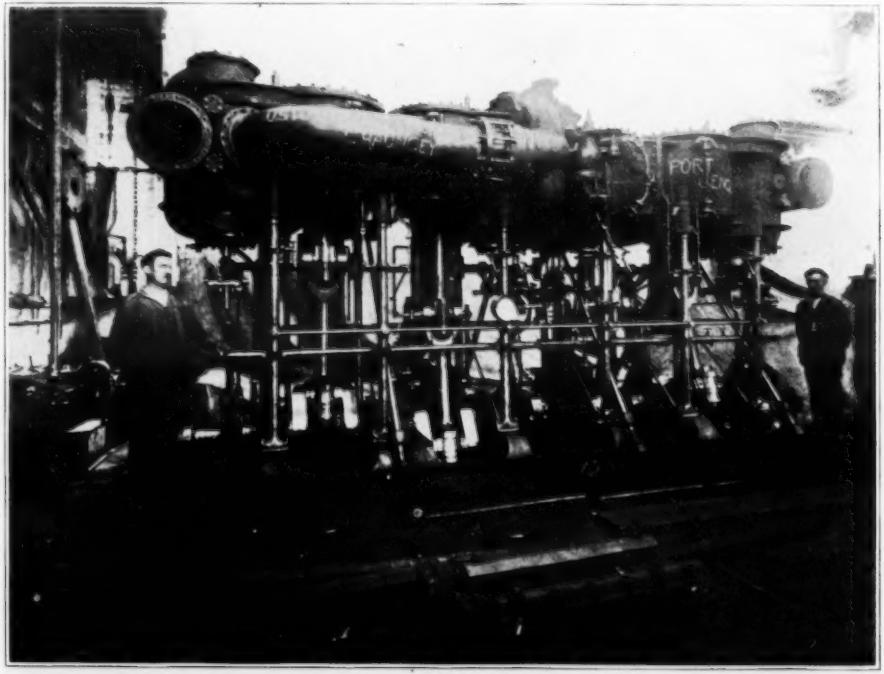
The *Bainbridge* was launched August 27th, 1901, with all machinery and boilers on board, and steam on forward boiler. Immediately after the vessel was brought alongside of the dock the engines were uncoupled and a dock trial was made. The fact that all weights were on board before the vessel was launched caused an uneasiness in the minds of some, who feared, because of the lightness in construction of the hulls of boats of this class, that the hulls would change shape somewhat and throw the shafting alignment out. The uncoupling was done between thrust and line shafts, and when the engines were run uncoupled the male on the thrust shaft coupling flange turned freely in female of line shaft coupling flange, showing that the alignment had not been disturbed. The following day, all blocking having been cleared away from under the vessel, a second dock trial was made with engines coupled.

On September 3d, 9th, 12th, 17th and 23d, short trials in the Delaware River were made to break in the engineer's crew.

During the trial on the 12th the main steam stop valve on No. 2 boiler closed automatically, caused by the opening of the pilot valve in connection with the automatic system for closing the stop valve on this boiler. It is supposed that the vibration of the vessel caused the pilot valve to open.

On the trial of the 23d steam was gotten up for the first time under all four boilers. Several runs were made over the measured-mile course off Wilmington, Delaware. Owing to too shallow water on this course for boats of this class to be speeded, no attempt to attain a high speed was made. All blowers were run slowly with fire-room hatches open, thus obtaining assisted draft. With steam at about 150 pounds and 225 revolutions per minute a speed of nineteen and one-half knots was made.

The first trial of the *Bainbridge* in deep water was made on October 8th, 1901, at the mouth of the Delaware Bay.



TYPE ENGINE OF DESTROYERS "BAINBRIDGE," "BARRY" AND "CHAUNCEY."

This trial was made under forced draft of ¾ inch in forward fire room and about 1⅛ inches in after fire room. The after smoke pipes heated so much that the paint on the outer casing of the smoke pipe was burned off. This was attributed to the small area through air doors underneath the furnaces of the after boilers. The shafting running underneath these boilers necessitated shallower ash pans than under the forward boilers, and, of course, small air doors underneath the furnaces. This fault was corrected by pocketing the floor plates in front of these boilers and increasing the size of air doors, making the same area as on forward boilers.

These changes having been made, another trial over the same course was attempted on October 18th, but bad weather and heavy seas caused the trial to be abandoned. The following morning, the weather having moderated somewhat, it was decided to have the trial. There was a strong S.S.W. wind and rough sea, the sea making it difficult to keep the vessel on a straight course, particularly on the runs north, and necessitating at all times a constant working of the helm. Four double runs were made over the measured course, after which the trial was abandoned on account of increasing unfavorable weather conditions. The maximum average speed for a double run was 26.66 knots. At the beginning of the trial the tell-tale gear for both engines broke, and it was inoperative during the trial. A complete set of indicator cards was taken. After this trial it was decided to make no further attempt to speed the *Bainbridge* over the course at the mouth of the Delaware Bay, because of the almost constant unfavorable conditions of the weather and sea for vessels of this class and speed. On the trials of the *Bainbridge* in the Delaware River and Bay, there were no mishaps or accidents to the machinery. An occasional crosshead and crank pin heated slightly, and the high-pressure piston rod of forward engine heated on two occasions, but never any damage done. The engines worked smoothly and without undue vibration.

The third builders' deep-water trial was made over the measured course of one mile in Narragansett Bay, November 19th,

1901. Eight double runs were made over the course. On the second run over the course the starboard after blower stopped because of the jamming of the lower bearing, rendering the blower inoperative for the rest of the trial. The steam was not well maintained over the course.

Following this trial, the *Bainbridge* was docked, cleaned and painted, and again tried by the builders over the same course on November 23d. Another eight double run was made over the course, with a maximum average speed for a double run of 27.74 knots. A constant steam pressure could not be maintained. At the end of the measured-mile course, the steam pressure was from 15 to 30 pounds less than at the beginning of the run. The engines ran smoothly with no excessive vibration. In working up the indicator cards taken on the trials of the 19th and 23d it was found that the power was not divided equally among the four cylinders, and a resetting of the valves was necessary. After these trials it was decided to hold no more trials over the Narragansett Bay course, there being too little room in which to turn to get back on the course again, also the course was seldom clear of traffic.

New valve diagrams having been made and valves reset, the *Bainbridge* was taken to the Barren Island course in the Chesapeake Bay, and on January 13th, 1902, a trial was made, but one of the blowers gave trouble and the trial was called off.

On the 15th a standardizing trial was attempted, but the blowers again gave trouble, the vanes of the fans bending badly. The builders of the blowers decided to make heavier fans and with top bearings. The *Bainbridge*, returning to Philadelphia from the Chesapeake Bay on January 18th, had to break her way through ice from 3 to 4 inches thick all the way from Ship John Lighthouse to the dock, a distance of about 65 miles. At times it was necessary to go ahead at a speed of 20 knots to break her way through. No damage was done to the hull.

The new blower fans having been installed, attempts were made May 19th and 20th to standardize, but each time the blowers failed, and the trials were unsuccessful.

June 11th an unsuccessful standardization trial was made. A

leak developed in the brazing of the inlet nozzle of main exhaust on port condenser, causing a rapid drop of vacuum in the condenser. Temporary repairs having been made, the trial was resumed the following day, June 12th, but failed to make the required 28 knots, caused by failure to maintain a constant steam pressure. During the last two runs the steam pressure fell rapidly, the difference of pressures at the beginning and end of runs being 20 and 25 pounds.

ONE-HOUR ENDURANCE TRIAL OF THE *BAINBRIDGE*, JUNE 12, 1902.
COURSE, BARREN ISLAND.

TABLE I.—"BAINBRIDGE," STARBOARD ENGINE.

Time, P. M.		Revolutions of engine.	Revolutions per minute.	Steam pressure above atmosphere.			Vacuum.	Air pressure in forward fire room.
				Steam pipe.	First receiver.	Second receiver.		
hrs.	*mins.*							
5	30	...	...	175	73	12	25	3.5
5	40	...	300.8	185	80	16	24.7	4
5	50	...	308.2	190	82	18	24	4.2
6	00	...	299.5	200	85	20	24	4.2
6	10	...	302.3	205	85	19	24.1	4
6	20	...	303.9	185	76	18	24.5	4
6	30	...	294.6	177	73	16	25	3.6
Mean,		...	301.55	188.1	79.1	17	24.5	3.93

TABLE II.—"BAINBRIDGE," PORT ENGINE.

Time, P. M.		Revolutions of engine.	Revolutions per minute.	Steam pressure above atmosphere.			Vacuum.	Air pressure in after fire room.
				Steam pipe.	First receiver.	Second receiver.		
hrs.	*mins.*							
5	30	...	...	177	70	15	22.5	3.8
5	40	...	304	190	76	17.5	22	4.5
5	50	...	314.5	215	90	22.5	20.5	4.5
6	00	...	307	205	82	21.5	20.5	4.5
6	10	...	308	205	83	20.5	20	4.4
6	20	...	306.5	195	75	19	21	4.1
6	30	...	299	190	73	17.5	21	4
Mean,		...	306.5	197	78.4	19.1	21.1	4.26

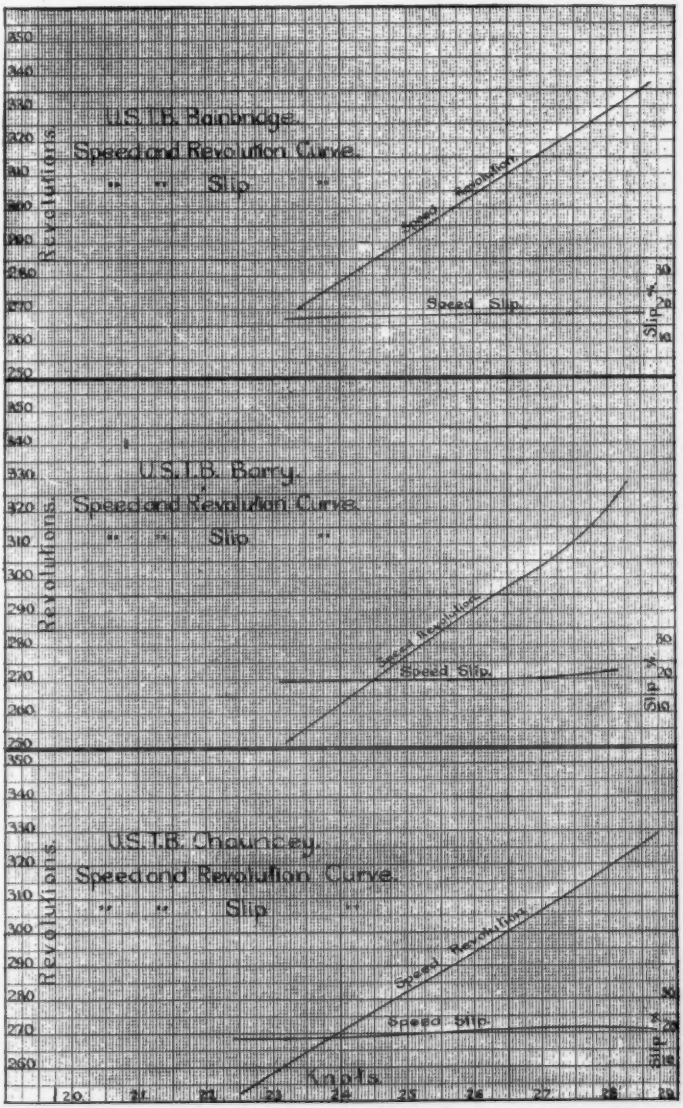
STANDARDIZATION TRIAL OF THE *BAINBRIDGE*, SEPTEMBER 11, 1902. COURSE, BARREN ISLAND.

TABLE III.

.....	First double run.		Second double run.		Third double run.		Fourth double run.	
Duration of run, minutes and seconds	2 31.5	2 36.2	2 16.2	2 23.5	2 04.5	2 08.2	2 13	2 16.2
Total revolutions each run by counter, starboard	680	704	681	708	688	709	687	707
port	684	709	689	725	704	721	700	716
Mean revolutions per minute during double run	270.75		300.65		334.55		313.2	
speed of vessel in knots	23.41		25.76		28.452		26.75	
slip of screws	17.27		18.01		18.59		18.25	
Steam pressure above atmosphere in main steam pipe, stbd.	135.7	132	178.3	175	230	226.7	201.7	195
port.	138.3	136.7	186.7	180	226.7*	235*	203.3	207
Ditto, 1st receiver, starboard	51	48.7	68	66.7	88.3	85	76	73.7
port	49.3	48.7	67.7	69	86	90	76.7	75.7
2d receiver, starboard	4.3	3	9.5	8.7	17.3	15.7	15	13.3
port	5.2	5.2	11.3	10.3	21	22.7	16.7	15.7
Vacuum in inches of mercury, starboard	24	24	23.3	23.3	22.7	22	22	22.8
port	24	24	23.2	23.2	21.8	21.2	22.3	23
Air pressure in forward fire room, inches	1.12	.75	2	1.75	6.75	6	6.5	2
after fire room, inches	.81	1.12	1.75	1.75	6.5	7.75	2.75	3.75

Mean draught, 7 feet $\frac{11}{16}$ inch. Displacement, 460 tons. Exhaust from blowers delivered to feed-water heaters and 2d receiver. H.P. cut-off, 16¼ inches instead of 17 inches as designed.

* Safety valves blowing off.


U.S.T.B. Bainbridge.
Speed and Revolution Curve.
" " Slip "
Revolutions.
Speed Revolution
Speed Slip
Slip %
U.S.T.B. Barry.
Speed and Revolution Curve.
" " Slip "
Revolutions.
Speed Revolution
Speed Slip
Slip %
U.S.T.B. Chauncey.
Speed and Revolution Curve.
" " Slip "
Revolutions.
Speed Revolutions
Speed Slip
Slip %
Knots.

In the afternoon of the same day a successful one-hour endurance trial at a speed of 26 knots was made. On the trials of June 11th and 12th the blowers had been reversed so as to run with the concave surfaces of the blades on the go-ahead side. This change was in no wise an improvement over the regular arrangement of running the blowers, so the steam valves were set for the fans to run in the usual direction. Up to this time a constant steam pressure, high enough to standardize at 28 knots, could never be maintained in the boilers. The smoke pipes would flame, showing there was not complete combustion. It was decided to fit additional baffle plates in the back connections of the boilers. The baffles contracted the area through which the gases would pass at back end of the boilers on their way to the smoke pipes and compelled the gases to return between the water walls formed by the generating tubes, as apparently they did not do to the extent they should have done. After this was done there was evidently more complete combustion, for a more constant steam pressure was maintained, with no heating or flaming of the smoke pipes. This same modification was carried out on the *Barry* and *Chauncey* with good results.

A successful standardization trial of the *Bainbridge* was made over the Barren Island course in the Chesapeake Bay September 11, 1902, making a maximum average speed of 28.45 knots for a double run.

On the third double run of the *Bainbridge*, when making the highest speed, and at a pressure of about 235 pounds at the engines, the safety valves blew off. This was due to a mistake in the setting of the safety valves after removing the springs from the combination stop and reducing valves on boilers. Had it not been for the opening of the safety valves, a higher speed, no doubt, could have been obtained.

CHAUNCEY'S TRIALS.

The *Chauncey* was launched October 26, 1901, with all machinery and boilers on board, and steam on forward boiler. The engines were first run at a dock trial on November 5th. The

same alterations to air doors under furnaces of after boilers was put into effect as for the *Bainbridge.*

On November 9th, the first river trial was made. The high-pressure piston rod of the starboard engine heated up, and the vessel returned to the shipyard. The second and third river trials were made on November 11 and December 18, respectively. These trials were only to put the machinery in good working order. Before another trial could be made, the contractors, benefitting by the change in valve setting of the *Bainbridge*, reset the steam valves of the main engines of the *Chauncey.* The makers of the blowers also furnished new fans for fire room blowers.

April 29th, 1902, the *Chauncey* was docked at Baltimore, cleaned and painted, and on May 8th given a trial in the Chesapeake Bay. No successful results were obtained on this trial, because of the failure of the blowers.

June 14th an attempt to standardize was made, but a constant high-steam pressure could not be maintained, and the *Chauncey* failed to attain the twenty-eight knot speed required for a successful standardization.

The next step taken was to fit additional baffle plates in back connections of boilers, as was done on the *Bainbridge* and *Barry.* The *Chauncey* was again docked August 5th at Baltimore, and on August 11th made an unsuccessful standardization trial, the blowers again causing trouble. August 12th, successfully standardized at 28.64 knots. August 13th, successful one-hour's endurance trial at 26.73 knots as an average for the hour.

After the one-hour's speed trial, turning trials were made at a speed of about 26 knots. The helm was put from amidships to hard-a-port in 5½ seconds, and from hard-a-port to hard-a-starboard in 11 seconds. The estimated diameter of the turning circle was 225 yards approximately. The list of the boat with full helm angle was about 10 degrees.

The steam-steering gear was then tried by running the vessel at a speed of 26 knots with the helm amidships and, after an interval of one minute, reversing at half speed. On beginning to go astern the helm was put about 20 degrees a-port, and on reach-

STANDARDIZATION TRIAL OF THE *CHAUNCEY*, AUGUST 12, 1902. COURSE, BARREN ISLAND.

TABLE IV.

.....	First double run.		Second double run.		Third double run.		Fourth double run.	
Duration of run, minutes and seconds	2 33.1	2 43.2	2 22	2 27.4	2 02	2 09.6	2 08	2 13.7
Total revolutions each run by counter, starboard	660	697	657	704	673	711	710	701
port	650	686	657	693	665	699	663	697
Mean revolutions per minute during double run	255.55		280.85		327.55		312.85	
speed of vessel in knots	22.79		24.88		28.64		27.52	
slip of screws	18.75		19.46		20.57		21.28	
Steam pressure above atmosphere in main steam pipe, stbd.	142	132	174	174	250	247	224	222
port.	141	135	172	177	250*	247	224	222
Ditto, 1st receiver, starboard	45	42	59.3	45	82.5	85.7	76	76.3
port	45	42.3	61.7	62.3	93.3	91.7	81.3	81
2d receiver, starboard	5	4	10	11.5	25	24.7	18	19.3
port	6	5	10.2	11.6	25	23.5	18.8	20
Vacuum in inches of mercury, starboard	24.6	25	24.4	24.7	21.8	21.5	23	23
port	24.75	24.7	24	24	21.8	21.7	22.7	22.5
Air pressure in forward fire room, inches	$\frac{3}{8}$	$\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$6\frac{1}{2}$	8	$4\frac{1}{2}$	$3\frac{5}{8}$
after fire room, inches	$\frac{1}{4}$	$\frac{1}{4}$	$3\frac{1}{2}$	$2\frac{1}{2}$	9	$8\frac{1}{2}$	$4\frac{1}{2}$	3

Mean draught, 7 feet $2\frac{1}{4}$ inches. Displacement, 463 tons. On the trial the exhaust from blowers which was not used in feed-water heaters was put into the 2d receiver of main engines. The H.P. links of main engines were set so as to cut-off at 16 inches instead of 17 inches as designed.

* Safety valves blowing off.

ing this point the port wheel rope carried away at the pelican hook where connection is made to the hand-wheel rope.

ONE-HOUR ENDURANCE TRIAL OF THE *CHAUNCEY*, AUGUST 13, 1902. COURSE, BARREN ISLAND. COAL CONSUMED DURING THE ONE HOUR, 18,100 POUNDS OF PICKED POCAHONTAS.

Displacement, 463 tons.

TABLE V.—"CHAUNCEY," STARBOARD ENGINE.

Time, A. M.		Revolutions of engines.	Revolutions per minute.	Steam pressure above atmosphere.			Vacuum.	Air pressure in forward fire room.
				Steam pipe.	First receiver.	Second receiver.		
hrs.	*mins.*							
9	0	...	...	205	68	16	24	...
9	10	3,009	300.9	210	70	17	24	...
9	20	3,044	304.4	220	75	19	24	...
9	30	3,001	300.1	225	75	20	24	...
9	40	3,043	304.3	210	72	19	24	...
9	50	3,077	307.7	225	77	20	23½	...
10	00	3,122	312.2	220	73	19	24	...
Mean,		...	304.95	216.4	72.9	18.6	23.93	3.5

TABLE VI.—"CHAUNCEY," PORT ENGINE.

Time, A. M.		Revolutions of engines.	Revolutions per minute.	Steam pressure above atmosphere.			Vacuum.	Air pressure in after fire room.
				Steam pipe.	First receiver.	Second receiver.		
hrs.	*mins.*							
9	00	...	...	205	70	15½	23	...
9	10	2,995	299.5	210	75	17½	22½	...
9	20	2,991	299.1	215	80	19	22	...
9	30	2,992	299.2	220	85	20	22	...
9	40	3,035	303.5	215	82	18½	22	...
9	50	3,046	304.6	225	84	20½	22	...
10	00	3,084	308.4	215	85	19½	22	...
Mean,		...	301.7	215	80.1	18.7	22.2	4

BARRY'S TRIAL.

The *Barry* was launched March 22d, 1902, with all machinery and boilers on board, and steam on forward boiler. Two hours later she went down the river for a three-hours' trial. Before the

*Safety valves blowing off.

STANDARDIZATION TRIAL OF THE *BARRY*, AUGUST 27, 1902. COURSE, BARREN ISLAND.

TABLE VII.

.....	First double run.		Second double run.		Third double run.		Fourth double run.	
Duration of run, minutes and seconds	2 32.1	2 38	2 15.3	2 26.1	2 07	2 09	2 10.2	2 16.2
Total revolutions each run by counters, starboard	648	692	645	700	685	715	652	705
port	640	684	650	686	674	691	652	688
Mean revolutions per minute during double run	252.5		285.8		324		303.7	
speed of vessel in knots	23.226		25.625		28.126		27.04	
slip of screws	19.26		19.27		22.43		20.32	
Steam pressure above atmosphere in main steam pipe, stbd.	125	138.3	178.3	180	235	240	211.6	202.3
port.	130	138.3	176.6	171.6	245	238.3	210	205
Ditto, 1st receiver, starboard	50.7	56.3	77.2	75	115.6	115	98	96
port	53	57.6	75.7	73	115	113	96	92.7
2d receiver, starboard	5.7	8.5	13.8	13.3	25	24	19	20
port	7.3	9.2	15.5	15.2	28.6	26.3	20	20.7
Vacuum in inches of mercury, starboard	25	25.2	26	25.5	25	24	23.5	23.5
port	25.8	25.5	24.5	25	22	22	23.5	23.8
Air pressure in forward fire room, inches	1.5	1.27	2.75	2.75	7.37	7.62	6.37	6
after fire room, inches	1.75	.1	3	2.4	7	7	2.12	2.5

Mean draught, 7 feet $1\frac{5}{8}$ inches. Displacement, 461.6 tons.

ONE-HOUR ENDURANCE TRIAL OF THE *BARRY*, AUGUST 28, 1902. COURSE, BARREN ISLAND. COAL CONSUMED DURING THE ONE HOUR, 12,800 POUNDS OF PICKED POCAHONTAS.

Mean draught, 7 feet 1 inch. Displacement, 461 tons.

TABLE VIII.—"BARRY," STARBOARD ENGINE.

Time, A. M.	Revolutions of engines.	Revolutions per minute.	Steam pressure above atmosphere.			Vacuum.	Air pressure in forward fire room.
			Steam pipe.	First receiver.	Second receiver.		
hrs. mins							
7 04½	...	...	180	80	16	25	5½
7 14½	...	295	200	88	20	23½	4½
7 24½	...	300.9	200	90	20	24	4½
7 34½	...	309.4	215	100	23	23½	4½
7 44½	...	310.6	210	98	22	23½	4½
7 54½	...	311.7	215	98	21	23½	3½
8 04½	...	300.6	200	90	18	24	4½
Mean,	...	304.7	202.9	92	20	23.9	4½

TABLE IX.—"BARRY," PORT ENGINE.

Time, A. M.	Revolutions of engines.	Revolutions per minute.	Steam pressure above atmosphere.			Vacuum.	Air pressure in after fire room.
			Steam pipe.	First receiver.	Second receiver.		
hrs. mins.							
7 04½	...	...	180	75	14	24	3
7 14½	...	290.9	200	76	18	24	3
7 24½	...	293.9	200	85	18	24	3
7 34½	...	304.4	205	95	20	23½	4½
7 44½	...	307.7	215	100	21	23½	5
7 54½	...	308.5	210	100	22	23½	5
8 04½	...	296.2	205	95	20	24	3½
Mean,	...	300.2	202.1	89.4	19	23.8	3.8

vessel was launched the same change was made to the air doors under furnaces of after boilers as was made on the *Bainbridge*. The steam valves on main engines were also reset. The makers of the blowers also made and installed new fans on fire-room blowers. A second builders' trial was made in the river March 28th, 1902. On these two trials the engines ran smoothly, with no heating or mishap of any sort.

July 2d, 1902, the third river trial was made after fitting additional baffle plates to back connections of boilers. This trial was the first of the three boats after the fitting of the baffle plates, and the results showed that the modification was a beneficial one. July 30th, 1902, the *Barry* left the ship yard for the Barren Island course in Chesapeake Bay, and on August 2d a preliminary trial was made. On the sixth run over the course the starboard forward blower broke down. August 27th the *Barry* successfully standardized at 28.12 knots.

August 28th, successful one-hour's endurance trial at 26.89 knots as an average for the hour.

After the one-hour's speed trial, turning trials were made at a speed of about 26 knots. The helm was put from amidships to hard-a-port in $7\frac{3}{4}$ seconds, and from hard-a-starboard to hard-a-port in 11 seconds. The estimated diameter of the turning circle was 275 yards. The list of the vessel with full helm angle was approximately 8 degrees.

On attempting to test the steering gear while going half speed astern, the main engines running at about 200 revolutions, it was found impossible to make a test of the steering gear due to slack wheel ropes.

Just before the official trials of the *Bainbridge*, *Barry* and *Chauncey* were run the springs in the combination reducing and steam stop valves on boilers were taken out of the valves, as the contractors had some doubt as to their proper working.

It may be interesting to note that when the *Bainbridge*, *Barry* and *Chauncey* were docked previous to their successful official trials, the lead-pencil marks made on the blades of the propellers while in the machine shop, to measure the pitch of the propellers, still showed distinctly on the blades. The marks were not scratched on, but made with a medium-hard lead pencil.

On the trips of these vessels up and down the coast to reach the trial course some very rough weather was encountered, and their actions showed them to have good sea-going qualities.

THE REPAIR SHIP A MILITARY AUXILIARY TO THE NAVAL FLEET IN PEACE AND WAR.

THE NECESSITY, PURPOSE AND CHARACTER OF SUCH A VESSEL.

By Lieutenant Commander F. W. Bartlett, U. S. N., Member.

THE REPAIR SHIP IN TIMES OF WAR.

It is well recognized, from the experience in the last war, that the repair ship is an absolute necessity for each fleet in war times. The numerous reports about the Repair Ship *Vulcan* made by the commanding officers and chief engineers of all ships that took part in the Santiago blockade show conclusively that the repair ship was as important as any one element could be in deciding that campaign. The blockade could not have been kept up as effectively without the repair ship; the smaller ships would not have been able to do scout duty close to the entrance of the harbor at night; and the torpedo boats would have been of little use.

Those who were on the scene at Guantanamo Bay observed that at the moment any ship anchored in the harbor one or two boats put off immediately to the *Vulcan* with repair work or with requisitions for mechanics to do repair work on board. This was the first thought of every commanding officer and of every chief engineer, and everything was subordinated to it. After the repair work was considered, other matters, such as getting fresh provisions and reporting events of last trip, were attended to.

The *Vulcan* was surrounded at all times during the day, and often all night, with boats from various ships, each with a commissioned officer—not a petty officer or a coxswain—who personally went over with the repair work, followed it up, and brought it back to their respective ships. At any time, there could be found on board from three to ten chief engineers, who had left the work on their own ships to be attended to by their assistants, to personally assist in pushing their work on the *Vulcan*. Many

commanding officers came on board also to try and induce the officer in charge of the work to hurry their work along, as each one considered his own work the most important.

Among other work accomplished, a large tug was entirely fitted out with a battery, which the enterprising lieutenant in command had appropriated at Key West. Whenever he saw a rapid-fire gun that seemed to have no owner he sent a boat ashore and whisked it off to his ship, so that when he arrived at Guantanamo Bay he had some guns with mounts and some guns without mounts, and these guns were installed by the force of the *Vulcan*. After the installation of the guns, the lieutenant in command demanded ammunition for them, and soon after took part with great effect in one of the engagements at Manzanillo.

Another operation, which was very extensive, was overhauling the gun carriages and mounts on one of the large cruisers. This cruiser took part in one of the bombardments of the forts at Santiago and was handled with great gallantry, going directly into the mouth of the harbor in the face of a heavy fire. As the forts were high, her guns were fired at their greatest elevation, and at the end of the two-hour bombardment the mounts were all more or less out of order. Thorough repairs were made on the *Vulcan*, and the ship was again ready for duty.

The boilers of many ships were entirely retubed, saving, thereby the time that would have been required to go to the nearest navy yard, at Norfolk, Va., and return, a matter of over two weeks. Smaller repairs of all kinds were made on all sorts of craft. Torpedo boats were always out of order. There never was a day but that work was being done on all of them, and without the repair ship they would have been absolutely worthless.

After the surrender of the forces at Santiago, the battleships, which had so magnificently maintained the blockade, all required more or less overhauling, and the work went on night and day in fully repairing all the ships for the demonstration on the coast of Spain. After this demonstration was abandoned, the ships were again put in condition to go north for thorough overhauling.

Another distinctive use of the repair ship then came into play, and without the repair ship it would have been impossible to have carried on the attempted operations. The sunken cruiser *Maria Teresa* was to be raised by contract by a wrecking company. This firm went about it with the usual facilities, but it was soon found that the operations were hopeless with the tugs and force of men which they had available, so the *Vulcan* was called upon to assist. Mechanics of all kinds were put on board, and the *Vulcan* went to the scene and assisted in raising the ship and in towing her fifty miles to Guantanamo Bay, where she was safely anchored. The force of the *Vulcan* worked on her for six weeks, overhauling her machinery and repairing her in every way, getting her ready to come north. The *Vulcan*, her work at Guantanamo Bay having been concluded, assisted in towing the ship until the final catastrophe at Cat Island.

In the Philippines, after the battle of Manila, the repair ship would have been invaluable. The shops on shore at the naval station were inadequate, and with the very worst types of machinery, and very few machines at that. Our own ships could have been immediately repaired, as necessary; the Spanish ships floated, put and kept in good condition; and the sunken ships could have been raised before they had time to deteriorate, thereby saving the Government an enormous quantity of money and supplying very-much-needed vessels for patrolling the extensive coast of the Philippines. Instead of sending these ships to Hong Kong, with great loss of time and heavy expense, most of them could have been repaired by the repair ship just as rapidly, and the use of these ships preserved. After this, the repair ship could have gone around the island and visited the smaller ships and stations at detached points, also carrying supplies, moving troops, and acting as a general freighter.

Another extremely valuable use would be for cutting and repairing cables during war times, as was done by the huge *St. Louis* off Santiago, thus cutting the enemy's communications and reestablishing the lines for ourselves as found necessary.

These are only a few of the many uses of the repair ship in times of war. The matter has been so thoroughly brought into

prominence that there is no necessity of more remarks on that subject.

For an extremely interesting statement of the need of the repair ship in war times reference is made to an article published by the "Engineering Magazine" in June and July, 1899, written by Gardiner C. Sims and Wm. S. Aldrich, whose efforts on the U. S. Repair Ship *Vulcan* contributed very largely to her success.

THE REPAIR SHIP IN TIMES OF PEACE.

The argument has been advanced that the repair ship is not an absolute necessity in times of peace, and that thus there is no need of the repair ship. The same argument holds in regard to battleships and torpedo boats. In order to be ready and useful in times of war, they must be ready in times of peace. This applies to the one as well as the other. Besides this, the repair ship can be of great value in many ways in times of peace as well as in war times.

SOME IMPORTANT USES IN TIMES OF PEACE.

I. Station Ships.—The repair ship could go around a department like that in the Philippines, where ships are stationed for a long period of time. She could go from one ship to another, spending a few days with each ship and making the necessary repairs which could not be made on board, supply deficiencies of stores and material, carry men from one ship to another or to the central station, and be a general freighter from ship to ship and from ships to the central station. In this way the ships on the station could be kept in good condition, and could remain at their posts for a much longer period of time.

II. Detached Naval Stations.—The repair ship could be used to visit various detached navy yards or naval bases, and could do work on shore required for the naval service. She could go to Guam, for instance, stay there for three months, assist in building wharves and jetties, overhaul marine barracks, repair station ship, and deliver supplies. From there she could go to the Sandwich Islands and perform the same operations, and then to other stations.

III. New Naval Stations.—In starting new naval stations the repair ship would be of extreme value. New material for houses, wharves, and other purposes could be taken on board and delivered at the station, and the force on board could do the constructing and start the station in proper shape, and could leave the commandant fully installed until enlargement of the station is required or the shops are begun, when the repair ship could again appear with a force of workmen and material and hurry the work to completion. She would have been of great value at Tutuilla, and the work which dragged along for months could have been finished in one month. She would have been of immense value at Port Royal when the naval station was first started there. She would also have been of great value at Algiers when the drydock was towed there, and in repairing the same. The same applies to Bremerton when it was first started.

In November, 1899, the *Solace* was sent to the naval station, San Juan, carrying the commandant and other officers and a squad of forty marines to take charge of the station. At the last moment a complete evaporating plant, with necessary pumps, piping, etc., was put on board, as it was known that there was no good drinking water on the island. The officers, men and material were dumped on the beach and the ship departed in two days, leaving affairs in a state of confusion that it took months to straighten out. The buildings were in a filthy condition, not fit to live in, with mud floors, and the filth of two-hundred years permeating the soil. It was absolutely dangerous to drink the water, which was the drainage from roofs into large cisterns.

The different items of work were given out by contract; the buildings were scraped, cleaned, disinfected and whitewashed; a filling of six inches of coke was put over the mud floors, cement put above this, and a raised board flooring put above the cement.

The evaporating plant was put up by contract in a very imperfect manner with the miserable facilities in the engineering line in San Juan. The whole operation took over three months, and during this time the health of the personnel was materially affected by the water.

If a repair ship had taken the personnel and material to this

post, the entire work could have been accomplished at practically no expense, as the repair-ship force would always be under pay, and they could have finished the work in three weeks at the utmost, when the repair ship could have gone elsewhere to do other important work.

At present there is at Culebra a squad of marines who are starting a post. These marines have no water near by. The drinking water is brought from San Juan in lighters, or is given to them by whatever naval vessels happen to go to that post. They are left with no facilities or any kind of comfort.

When the fleet goes south during the winter, the situation will be much worse, as large forces of marines will be on shore, and enormous quantities of water must in some way be taken ashore daily. There are no buildings or storehouses of any kind for storage purposes or for any kind of comfort. If a repair ship had been sent to Culebra in the beginning, in less than a month the marines could have been housed, storehouses erected, a distilling plant installed, wharves for landing small boats built, and a proper post started.

When the island of St. Thomas becomes a part of the United States, a repair ship should take down the officers and enlisted force and material, which will, of course, be sent there at once for starting the naval post. In two or three months the station would be perfectly established.

Should naval stations be established at other points, the repair ship could take down a force of workmen and material and establish the station in a proper manner (except for the largest wharves) in one month; and when the wharves and the coaling arrangements are to be constructed, the repair ship could again take down the necessary piles, timbers, pile driver, etc., and this work could be done by the Navy with the utmost rapidity and in the best possible manner. The drydock at Havana, which is now out of order, could be best repaired by a repair ship, which should go there at once.

IV. Experimental Work.—One of the most important uses of the repair ship, and a thing that is very much needed for the benefit of the naval service and by the engineering world at large,

is for experimental work. This work could be carried on at all times, in port or at sea, whether the vessel is alongside a navy-yard wharf or steaming, doing repair work for ships or other naval establishments, or instituting new stations. Some of the work could be best done at sea, other kinds could best be done while at anchor, but every important problem could be solved in the way of experiments. In this way the ship could be an adjunct to the experimental station which will surely be established at the Naval Academy in a short time. After the experiments had been made at the Naval Academy they could be continued at sea on board the repair ship, so that conclusive results could be obtained and the question of the utility or efficiency of any new article or machinery could be absolutely and finally settled.

Some of the tests that could be carried out are as follows:

Coal.—Instead of testing coal, as is now imperfectly done for a period of 10 to 24 hours, the ship's bunkers could be filled with one kind of coal, and the ship could steam around the world, using this coal with tests of from 10 to 20 days' steady steaming at a time, so that the efficiency of the coal at sea would be absolutely settled. The tests in port, where irregular work is required of the boilers, would be extremely valuable.

Oil Fuel.—The same tests for burning oil could be carried out. The tanks could be filled entirely with one quality of oil, and tested at sea and in port, as in the case of coal.

Also types of burners could be tested. When one burner had been tested and reported upon, another burner could be tried, and thus during a period of one year it would be possible to practically, under actual steaming conditions both in port and at sea, answer the question in an authoritative manner as to the desirability of using that quality of oil with those types of burners. Combinations of coal and oil could be burned, and thus this uncertain subject, combined with the uncertain subject of types of burners and the methods of burning, could be absolutely settled under practical conditions on board ship.

Boilers.—The hatches over the boilers on the repair ship could be arranged so that any boiler could be rapidly removed and

another type of boiler installed and tested on board under actual steaming conditions in port and at sea. All of the boilers could be removed, and an entirely new set tested. The questions of kinds of fire bricks and baffle plates, size of grates, size of furnaces, etc., could be tested on long trips, and the economy and efficiency of the different boilers, and different methods of using the boilers, could be settled for good.

Packing.—Every type of packing for rods, for high steam pressure, low steam pressure, water pumps, hydraulic, oil, air, etc.; also for making large and small joints of all kinds for various purposes, could be decided under all conditions, and the best type settled upon for use in the naval service for the various purposes.

Evaporators and Distillers.—The many types of evaporators and distillers in the Navy and elsewhere could be experimented with for months, and accurate data taken and the final results achieved. It could be decided whether the multi-step evaporator is better for the naval service than the ordinary single-step evaporator. Experiments could also be made as to the best methods for aerating the water and sweetening it for drinking purposes.

Traps.—The subject of traps is another matter which the engineering world desires to have settled. At present no traps are perfect. Few are more than good, but some are a little better than others. Every type of trap could be installed on the repair ship, and special devices arranged for testing them in actual use. These traps should be tested in doing work for which they were designed, some for high pressure and some for low pressure. The data could be kept for months, and, when finally the results were achieved and the reports made, something of enormous value to everybody would be known to the world. There could be a battery of traps arranged in the most thorough manner, and data could be taken from these traps hourly for months, when the best trap would be certain to tell its story.

Air Pumps.—There are many good air pumps on the market, and it is difficult to tell which is the best for naval purposes. A different air pump could be installed on the repair ship for each long trip, and at the end of a period of six months another air

pump could take its place. In the course of time positive and accurate results would be on record, and the best air pump decided upon with surety. As new designs of pumps would appear, or as older designs of pumps were improved upon, tests could be made, so that each year the best type of pump could be decided upon for installation in men-of-war, large and small.

Pumps for all Purposes.—Pumps for feeding boilers, flushing, feeding evaporators, pumping fresh water, pumping oil, hydraulic pumps, centrifugal, etc., could be tested as above for long periods of time, and in the course of a few years it would be certain that the best pumps for their specific purposes could be settled upon.

Screw Propellers.—As the subject of screw propellers is both theoretically and practically indefinite, a different propeller could be put on the repair ship each time she is docked, and accurate data taken of the efficiency of these propellers at varying speeds and states of weather, and experimental data (on which alone the type of propeller is decided upon) would be watched for by the engineering world with great interest. Experiments could be made on four, three and two-bladed screws at the same pitch, running constantly at various speeds. The subject of vibration to the propellers could be studied on long runs, and some accurate results attained.

Engine Vibration and Balancing Engines.—This subject, which has been written upon at great length and on which many theoretical ideas have been advanced, could be thoroughly investigated. The schemes which work out so beautifully theoretically could be practically proved or disproved, and the inventor of the scheme could be allowed to personally watch his invention or pet theory, and could embark in the ship while the experiments were being made. Thus, in time, something positive on the subject would be known instead of theorized upon.

Oil in Engines and Boilers.—Experiments could be made with both vertical and horizontal engines of all kinds (this including pumps, of course), to see whether the use of oil could be absolutely eliminated in all steam cylinders. If it is found necessary to use oil in small or large quantities in any type of machinery, it may be possible to decide adversely to the use of that type on

board ship, or it may be possible to decide as to the quantity and quality of oil that it is advisable to use. The different types of carbon oil could be tested thoroughly, and the kind doing the least harm to the engines and boilers could be adopted. By testing these oils for long periods the effect on the interior of the boiler and the quantity of oil found in the boilers, in steam-pipe lines, in cylinders, condensers, feed tanks, etc., could be discovered, and devices could be experimented with for eliminating oil from these various places, thus solving one of the most difficult problems in steam navigation.

Lubricating Oils.—These could be tested in actual practice in every possible manner, both chemical and physical, by burning and flash tests, until the very best oil for use on board ship could be settled upon, and final tests for oil could be elaborated, so that thereafter there could be no possible question as to the Navy receiving the actual oil required for.

Ice Machines.—The various machines for refrigerating plants could be tested for long periods in the most accurate manner, the power to run them indicated, the temperature taken many times a day in the various parts—refrigerating pipes, scuttle butt, etc.; and the best machinery could be decided upon with certainty. The quantity of refrigerating space and the proper power of machinery could be known accurately, both as regards ice making alone and for their refrigerating capacity under long conditions of service in cold and warm climates, and the machines decided upon that would be amply large enough to do work in the tropics, and not simply large enough to stand the tests during a cold northern winter, as is often the case at present. The best methods of making refrigerating rooms and for keeping pipes at a low temperature could be studied thoroughly. The machines could be tested for safety and accessibility, need of repairs, etc., and it could be decided positively what spare parts it would be advisable to carry for the various machines. In fact, the subject of the refrigerating plant could be definitely settled, until a better machine were tried, which could be compared with previous results.

Air Compressors for Torpedoes.—This is a very important sub-

ject for tests. There are many of these machines on the market, and it is practically impossible to distinguish which machines are the least bad except by long and accurate tests, which are not made at present. These machines could be run up to their limit for months on the repair ship, and could be worked to destruction. A dozen of these machines could be installed in a battery, all working up to the required torpedo-charging pressure, and the best machine would win. It would be possible to determine the ease of repairs and special defects of each machine, the necessary space occupied, the weight which is so important in torpedo boats, and all other matters connected with these extremely delicate and important machines. The best reservoir for compressed air for this purpose, and the necessary size of the reservoir, the type of valves for the pipe line, the type of the separator, type of union couplings, etc., could be investigated at the same time, and the very best chosen.

Pneumatic Plant.—As compressed air is in use nearly everywhere on shore and is largely used at the navy yards, the probability is that after this power is once used on the repair ship in the repair shops, and carried to vessels alongside under repairs, it would be used very extensively on vessels both in the Navy and merchant service. The various types of air compressors for this purpose could be installed on board the repair ship in a battery working to a pressure of 100 pounds, and worked constantly day after day until thoroughly tested. The pressures should be varied, whether the tools are in use or not, and varied suddenly at times, so that the machines would be tested in the best possible manner. The best type of air compressors, tank, valves, separator, pipe lines, manifolds, rubber hose, pneumatic tools, chippers, calkers, drills, lifts, etc., could be decided upon. The tools should be used in the most difficult kinds of work and in the most difficult situations, and accurate data taken of the results.

As new types of machines are designed or as improvements are made additional tests could be carried on, and the best machinery known could be installed at the navy yards and shore stations and on board ships. By using these tools in the engine room on board the repair ship it would be possible to determine the advis-

ability of installing air compressors on all men-of-war. It is thought that the work of overhauling machinery on board ship would be very much facilitated by pneumatic lifts, pneumatic rotators for removing and putting on nuts or parts of machinery, etc. It is undoubtedly a fact that the scaling of boilers can be done much quicker and more thorough by the use of pneumatic tools.

Boat Cranes and Davits.—Different types of these could be experimented with to great advantage. Besides studying the different designs for hoisting small and large boats the question of the power to be used could be thoroughly investigated. At present we have steam and electric hoists for this purpose, but it is almost impossible to get any comparative data on the subject. By trying all types of steam, air, and electric hoists on board the repair ship the matter could be thoroughly ventilated, and a decision arrived at as to which is the best for the various purposes. There could be placed on board at the same time two or three large and two or three small hoists using these three powers, and a comparison could be made, and a cruise of six months would determine positively which is the best to be used for naval purposes.

Electric Plant.—This repair ship would give an excellent opportunity for testing the many features connected with an electric plant on board ship. With the power required there would be three or four dynamos on board. These should be of different types, and certain dynamos should be connected with certain machines, search lights, etc., and others should be connected with still different apparatus. Their duties should be interchanged, and a decision of value arrived at. Besides testing these machines for economy and durability the subject of voltage should be investigated, and the best system of pipe lines, etc., should be decided upon. In fact, innumerable tests could be made of the entire electric plant, and valuable data obtained for deciding on the types of machines, type of current used, types of motors used, types of motors for various purposes compared with the use of steam, etc.

Electric and Hydraulic Welding.—Experiments under skilled operators could be made on this little-known subject to great

advantage, and the capabilities and efficiency of the two systems solved for the benefit of the engineering world at large.

Oil Retorts.—Having on board a supply of oil and air pressure, the use of oil in retorts for blacksmith work, etc., could be studied and valuable reports made. The questions of quantity of oil, air pressure, whether oil pressure is advisable, types of bricks, types of furnace, types of valves, temperatures of furnaces, etc., could be much elucidated on the repair ship, and the reports would settle the possibility of using oil for this purpose both at navy yards and industrial establishments.

Auxiliary Machinery.—Tests could be made on the repair ship that would tend to settle finally as to which power is best adapted for running auxiliary machinery on board ship. Besides tests for efficiency and heat producing effects of the types and the dangers of freezing, the life of the machines, etc., could be established.

Coaling at Sea.—Important experiments in this direction could be carried on, both for large ships and for torpedo boats. For coaling the large ships the repair ship could either tow or be towed, and special devices for this purpose could be experimented with, all the operations studied, and the best method settled upon. For coaling, torpedo boats could be towed by the repair ship, either directly astern or on the quarter, as found advisable, and special devices for these small craft could be studied and experimented with. Experiments could also be conducted with ships traveling alongside of each other or close together, or at a short distance from each other, and the most expeditious of the various methods determined. As it has been found that torpedo boats can safely steam with the bow of one boat touching the quarter of another boat, and that the position can be maintained with no difficulty and no danger in moderate weather, experiments could be made for coaling, supplying oil and water, etc., in this position, both with large and small craft. Very important results would certainly be obtained in a short time by having the repair ship and one or two other ships devoted to this purpose.

Wireless Telegraphy.—With the corps of workmen on board

the repair ship, and the many facilities for work, the many types of wireless telegraphy could be installed on board and tested separately or in unison, in communication with some fixed point on shore or with some other vessel, as found advisable. The originators of these various methods could accompany their devices and carry out experiments to their satisfaction, and thus the best method could be decided upon and installed aboard men-of-war and at shore stations.

Costs of Tests.—Inventors, designers, builders and contractors of the various special machines and special articles requiring testing would be only too thankful to install their machines on board the repair ship at their expense, and to give large quantities of material to the Government for experiments. In this way those who really have the best machines and best articles would be glad to have a test made, knowing that they stood a chance in having these authoritative tests given to the world. Those who had inferior articles or machines would never trouble the Government by having their articles or machines tested. It should be arranged that the agents for the various firms, etc., who would personally install their machines or articles on board, should be allowed to accompany the ship while tests were being made, the data, however, to be taken entirely by the representatives of the Navy.

Trustworthiness of Tests.—Any number of these tests could be carried on at the same time with the large corps of assistants available, and results could be achieved with great rapidity. The results, too, would be accurate, and the engineering world would accept them as absolutely unbiased and final.

V.—For Instruction at the Naval Academy.—During a part of each year, as found most advisable by the Superintendent of the Naval Academy, the repair ship could be secured at the wharf there so that the midshipmen could be taken on board whenever advisable and could study the various devices on board. When a certain subject had been studied during recitation periods, the same subject could be studied during the drill period on board the repair ship, and practical illustration given of the workings of each subject. The various power plants

could be started in operation, run and secured by the midshipmen, and their various uses explained, and the midshipmen could actually use the various apparatus driven by the plants. In this way they could get practical knowledge of steam, air, hydraulic and electric power in actual use, and practical and theoretical knowledge could be obtained at the same time.

The midshipmen could also assist in tests of various kinds carried on while the repair ship is at that station. They could be arranged in watches and actually conduct the experiments. They would be the best operators to be found anywhere for carrying out these tests, being absolutely under discipline and extremely accurate and careful while on duty. Boiler, engine and electrical tests could be actually performed by them while they are studying these subjects in the section room.

The repair ship could be utilized for taking a portion of the midshipmen on the summer practice cruise by temporarily removing the machine shops, etc., and by placing the men of the repair force on a receiving ship. Then the midshipmen could be taken to engineering establishments, and could acquire knowledge in engineering and shipbuilding. When at sea they could be experimenting with the different kinds of power on board, besides standing a watch with the regular power-plant force. For this purpose alone the repair ship would pay for the entire expense put upon it.

VI.—Rescue the Whaling Fleet.—Almost every year the whaling fleets in the Bering Sea get into difficulty, one or more of the vessels being frozen in the ice and swept northward with a certainty that the ship and all hands on board will never return. Daring trips are made by the small revenue cutters to rescue the crews of these ships. Severe hardships are borne, and the little ships have great difficulty in accomplishing their purpose and in returning with the rescued crews to safety. The repair ship, being always ready, could steam with great rapidity to these ships in the Northern Ocean, and, with its great weight, could force its way through the ice and rescue the crews, and possibly rescue the ships and tow them south. A ship the size of the repair ship could tow four or five ships with greater speed

than the small revenue cutters could tow one. It is considered that this would be one of the most valuable duties of the repair ship.

VII.—THE CANAL.—At the commencement of work on the Inter-Ocean Canal there will be need of sending certain officials, clerical force and guards, to represent the Government of the United States. These should be taken down in the repair ship, together with material for building houses for officers, wharves, etc., and the Government representatives could be installed comfortably and safely at their post of duty. Great assistance could also be given in the emergency of the contractors getting into difficulty with dredges, etc. The repair ship, with its large force of men and material, could assist materially in these emergencies, in hurrying on work of construction, and in assisting the American contractors in their work.

The repair ship would also be of great use in case of a revolution in the line of the canal, as she could carry down a force of marines and sailors, with their proper officers, and land them, supply them with water, food, etc., and the force on board could be rapidly dispatched to make repairs along the railroad, should the track be torn up or the cars overturned, etc.

VIII.—TORPEDO-BOAT FLOTILLA TENDER.—One of the most important duties in times of peace and in times of war of the repair ship would be that of "mother ship" to this flotilla of delicate vessels. The torpedo boats, with their light parts and sensitive mechanism, require constant nursing, and nursing of such a nature as only a repair ship can supply. Almost daily, small repairs would have to be done on the torpedo-boat flotilla, and thereby only could it be kept in a state of efficiency while on detached duty away from navy yards or stations.

The torpedo boats would always flock around the repair ship for repairs and supplies. The repair ship would be stationed in a quiet harbor near the scene of operations, and a torpedo boat could remain safely anchored until put into condition again for service. All supplies for the torpedo-boat flotilla would be carried on board the repair ship, so that the torpedo boats would be as light as possible. Spare propellers, spare engine parts, spare

boilers of different types, spare blowers, spare air compressors, etc., could be carried on board the repair ship, ready to be quickly installed on the torpedo boats to replace damaged ones.

It was the intention that a repair ship with these facilities on board should accompany the fleet during the winter maneuvers at Culebra, and the commanding officers of the torpedo craft at Norfolk, Va., were depending upon the repair ship, and were constantly discussing with the officer detailed for this duty the many ways in which the repair ship would be extremely valuable to the torpedo-boat flotilla. The disappointment of these commanding officers was great when it was found that the repair ship had been dropped, and they discussed with the officer detailed on the repair-ship duty as to how they should get along without it.

IX.—Tender for Fleet During Evolutions.—The same remarks apply in a lesser degree to the fleet when in evolutions. There would be less danger of accidents with the heavy ships and their heavy machinery; but accidents would constantly occur, and, although they might not disable the ship, the repairs would be necessary, and it would be a great convenience to leave the work to be done on board the repair ship while the fleet would be engaged in evolutions lasting two or three days and to find it ready on their return to the base, which would be practically the repair ship.

The conditions would be the same as in war times, except the time would be more limited and there would be no loss or destruction caused by hostile shots. The many letters from captains of ships and chief engineers state how exceedingly valuable the *Vulcan* was, and they would be very thankful to have a ship corresponding to the *Vulcan* with the fleet during the evolutions.

X.—Training Engineer's Force.—This subject has been experimented with in a tentative way to a very slight degree, but practically very little has been done in this direction. The men who would be particularly trained on the repair ship are: firemen, water tenders, oilers and second-class machinists. There would be enough boiler power under sufficiently varying con-

ditions on the repair ship to give the firemen and water tenders ample instruction, particularly if the idea of changing the boilers for experimental purposes should be carried out. In two or three years the firemen and water tenders could have experience with many types of boilers actually in use on board the repair ship and in steam launches, and would have opportunities to observe every type of boiler in use in the naval service while they were being repaired by the working force on board. The oilers and second-class machinists would have actual experience under way with the machinery of the ship, evaporators, dynamos, air compressors, hydraulic pumps, blowers and auxiliaries of the ship. In addition to this the second-class machinists could perfect themselves in machine work by assisting in the repair work carried on on board the repair ship. The training of blacksmiths, boilermakers and coppersmiths would be an extremely important feature, as these men would have exceptional opportunities for seeing and assisting in the types of repairs in their various trades.

XI.—Wrecks.—The repair ship could be dispatched at once to the scene of a wreck on the coast. With her great size and steadiness she could go out in all weathers, and with her large force of boats could be very valuable in saving the lives of the people in these wrecks. She could carry improved types of lines, throwing devices, breeches buoys, etc. She could lie to the windward of the wreck and distribute oil over the waters, could allow boats to drop down to the wreck in safety, and could readily save all on board. With her great weight she would be able often to pull wrecks out of dangerous positions and tow them into port. As the weather became quiet her divers could rapidly patch up the wreck, and could then attempt to float the vessel and tow her safely to port.

XII.—Derelicts.—The repair ship would be very valuable also in ridding the oceans of these floating dangers to navigation, by searching for them and blowing them up, or, if worth saving, by even towing them into port.

XIII.—Ocean Cables, Surveying.—This work would be exactly in line with the capabilities of the repair ship. When a

cable line should be planned the repair ship could run the lines of soundings with safety and rapidity, owing to her great size and weight. She could also hunt for broken cables, grapple and repair them, and thus serve the commercial world in peace times.

SUMMARY.—It must be seen that in times of peace the repair ship would be one of the most important ships in the naval service; in fact, the most important, as she would be able to perform many operations of absolute value in times of peace besides being always ready for war.

GENERAL REMARKS.

The general scheme of the repair ship should include:

1. Repair shops for all repairs except such as require docking or for a general breakdown, such as a cylinder, large engine casting, main shaft, connecting rod, or other large working part.

2. Evaporating plant and fresh-water tanks of large capacity for supplying water for ship's use and for boilers.

3. Extensive refrigerating plant and cold storage rooms, so that a sufficient supply of meats could be carried for the use of the fleet for a long period of time.

4. Bunker space and oil tanks more than sufficient for the use of the ship, so that torpedo boats could be coaled or supplied with steaming oil. The bunkers and tanks should be kept as full as possible by colliers and oil steamers.

5. General supplies, except provisions for the commissary department, sufficient to last the fleet for a period of six months. The commissary supplies should be furnished by regular supply ships.

6. Ordnance supplies in great quantities, to supply deficiency as required.

The repair ship is supposed to accompany a fleet in foreign waters, or anywhere, away from a naval base, where repairs cannot be made. She should carry material for repairs, and stores enough to last the fleet for a period of at least six months. At the end of this time supply ships could bring out enough material to make up for deficiencies. She should have a sustained speed

of at least sixteen knots under natural draft and eighteen knots under forced draft, so as to keep position with the fleet in all weathers. She should have gun protection sufficient to drive away torpedo boats and other small craft, and should carry searchlights and a complete signaling outfit for day and night use.

Officers.—The commanding officer and all other officers on board should be of the regular Navy. There should be an executive officer, navigator and at least four watch officers. There should be an engineer officer for the machinery of the ship, and another engineer officer in charge of all the shops on board. There should be at least four warrant machinists, to take the watches at sea in the engine room. In port one of the warrant officers should be detailed to assist the engineer officer of the ship, and the other three should be detailed to assist the engineer officer in charge of the shops. There should be a paymaster with a corps of assistants for the stores. There should be a medical officer with his corps of assistants. The deck officers should be chosen from those who have had special training in engineering work, so that they could be detailed to assist the engineer officer in charge of the shops when in port and when repair work is going on. There should be three warrant officers to take the deck watches in port and to assist the executive officer as found necessary.

In addition, there should be vacant rooms ready to receive at least ten officers or others who might require passage with troops or might be on board for experimental work.

Crew.—There should be an ample crew for deck and engine-room watches and for running the launches, and additional space, so that when necessary as many as two hundred extra men could be carried.

As the ship might be for many months away from all civilized regions every care should be taken for the comfort and amusement of those on board. Besides the care for ventilation, sleeping arrangements, diet, etc., there should be a reading room and gymnasium for relaxation when off duty. If possible, there should be a band on board, with brass and string instruments, so that

entertainments could be given by the crew, and that all could be enlivened and cheered by the music.

The duty of the repair ship would consist of periods of a rush of work, where all would work day and night, with periods of rest of greater or less length between. It would be very irksome duty, and the utmost care should be taken to keep the officers, crew and workingmen in condition so that they would work, when work had to be done, with enthusiasm and speed. During the intervals of rest every possible recreation should be allowed everybody—boat sailing, rowing and sailing races, fishing parties, seining parties, shooting parties, visits on shore, etc., should be encouraged on every occasion.

Charge of Shops.—The shops on board should be under the entire control of the engineer officer in charge of the shops, without regard to the departments under which the shops are installed. The commanding officer alone should have authority over the engineer officer in charge of the shops, and he should assist in every way possible with the work.

Repair and Supply.—Since the object of the repair ship is to repair and supply, everything else should be subordinated to those ends. The ship's force should give every assistance in hurrying the repair work on board and in delivering it to the repair shops, and, when finished, in hurrying it away. When supplying ships, every possible hoist and derrick should be manned, so that not a moment's delay would occur in hoisting material from holds and delivering it alongside, into boats, or on board vessels lying alongside. There should be a large force of assistants for the paymaster, both clerical and for labor, so that the bookkeeping would not delay one moment the delivery of supplies and so that his force below could be ready to rush the material out of the storerooms ready for the hoists.

A rapid system of receipting for the goods should be allowed by the Navy Department, and all necessary papers should be prepared by the paymaster's force on board. It is considered that the fighting ships should not be hampered in the least by the tedious paper work.

The ship should be large enough so that the largest battle-

ship could lie alongside, separated only by floats, so that repair work could be hastened, objects to be repaired quickly brought on board the repair ship, a force of workmen quickly put on board the other ships, the air-driven tools used, electric lighting supplied, and no time lost either in supplying material or labor.

Fresh Water.—The ship should have a double bottom throughout the entire length, for stowage of about 500,000 gallons of fresh water. These double bottoms should be absolutely tight, and should be used for carrying fresh water only. This fresh water should be supplied only by the evaporators on board, so that all of it would be ready for both boiler and drinking purposes. There should be evaporators to a capacity of at least 40,000 gallons per day. At least two pumps of large capacity should be ready at all times to pump water from any double bottom and supply it to boilers or drinking tanks of any ship within a half mile of the repair ship through standard Navy hose floated at the couplings by buoys.

Drying Hose.—Arrangements should be made for draining and drying the hose used for conveying oil and water to other ships. A yard for this purpose should be arranged on the foremast, so that it could be lowered to the deck, and so that several lengths of hose could be attached singly to the yard and the yard hoisted to a sufficient height to raise the bottom portions of the hose at least two feet above the deck. Tanks or buckets should be arranged to catch the water or oil.

There should also be an ample number of reels on the upper deck, under shelter, for stowing the hose.

Masts.—There should be two pole masts for signaling purposes only.

Boilers.—The boilers should be of a type that would steam economically, be easily overhauled, that would not readily get out of order, and would be capable of driving the ship at her speed without forcing.

Facilities for Repair Work.—The repair ship would be required to do work rapidly when work was to be done. Every tool on board should be of a type that would do the most work in the

shortest time. Cutting tools that would take the deepest cuts should be used. Everything should be subordinated to speed. Lifts of the most accurate and swift type should be installed in all parts of the ship, so that all lifting could be done without delay. Every possible device to save time in handling material should be installed. Nothing whatever should be left to slow hand power. The methods of getting out supplies should be of the most approved types for swift execution. The supplies should be in storerooms, arranged so that the loading and unloading could be done in the most rapid manner. As far as possible the articles on board should be hoisted by swift lifts and dropped into place at once without handling. Over all the hatches there should be at least four swift-acting lifts that could reach to any part of the space below and could carry the articles well clear of the ship's sides and over the hold of another ship alongside, allowance being made for a distance of at least twelve feet between the hulls. It should be possible to move the weights a horizontal distance of at least eighty feet. This could be arranged by placing the lifts at the side of the ship, two on each side for each hatch.

The repair ship should be capable of doing work of any nature except in the case of a general smashup of large engines. It should be possible to lift any boiler from a torpedo boat alongside and repair it on board. This also applies to any boiler of tubulous type that could be removed from any ship. It should be possible to hoist on board and repair any steam launch from the fleet.

Duplicate Machinery Carried.—There should be carried on board at least two of each type and size of tubulous boiler used in the Navy, so that the damaged boilers could be quickly pulled out of the ship and the new ones installed; then the damaged boiler could be repaired on board the repair ship ready for issue.

There should be carried on board at least two of each size and type of steam-launch engines and boilers, so that a damaged engine or boiler could be replaced by a new one, and the damaged one repaired.

There should be on board a certain number of condensers that

could replace damaged ones on torpedo boats. There should also be a number of keel condensers ready to be fitted on steam launches. There should be carried also two of each size and type of auxiliary condensers, ready to replace damaged ones, which could be repaired on board. Spare evaporators and coils of each class should be carried.

Pairs of screw propellers to fit the prevailing types on torpedo boats and steam launches, and spare blades for prevailing types on larger ships, should be carried. There should be carried pumps of all kinds and sizes in use in naval vessels.

There should be carried on board at least six steam launches, one of each of the prevailing types, so that one of these steam launches could at once be given to a ship to replace a damaged one, and the damaged launch repaired. If less than six types are in use in the Navy, these launches should consist of one of each of the types, and the remainder of the largest type. These launches would be needed at all times in conveying stores and repair work, and in towing boats loaded with workmen to and fro.

Cofferdams.—Cofferdams approximately fitting the sterns of torpedo boats should be ready for instant use, with ample supply of water-excluding material to make the proper fit. At least two divers' outfits, with skilled divers, should be carried.

Towing Machines.—Both at bow and stern the most improved types of towing devices should be installed, for use in coaling at sea and for towing disabled ships to a naval base.

Floats.—There should be at least four floats, 12 feet by 30 feet by 2 feet, carried on board and ready to be dropped over the side when in port, two forward and two aft, to fend off other ships lying alongside for repairs, as a landing place for men and stores, and also as an excellent place to do much small repair work.

Washing Machines.—There should be extensive washing and drying machines on board, so that the working and other clothes of the working force, crew and officers could be laundered on board, as it is practically impossible to expect the working force to wash their clothes in buckets on deck, as is now the custom

of the enlisted force; and the enlisted force would not have time in emergency of hurried work to wash their clothes; and the ship might be away from laundries for months, so that the officers would be unable to have their laundry done except on board.

Ice Plant.—There should be an extensive refrigerating and ice plant for the use of the ship only. This is extremely important, as men cannot do good work unless well fed, and the repair force would be unable, from lack of the sea habit, to keep in good health with the regular ship's ration. A refrigerating plant capable of making at least four tons of ice per day should be installed. The cold scuttle butt would be a very important matter to everybody on board, as the ship might remain in the tropics for months.

Spare ice plants of the prevailing types should be carried to replace damaged ones on other ships. Then the damaged ones could be repaired again ready for issue. Plenty of spare parts of ice machines should be carried also.

Space and Ventilation.—As this ship might spend months at a time in the tropics, the decks should be airy and not cut up by bulkheads, so that the air would have a clean sweep fore and aft. There should be heavy awnings with side curtains throughout the entire length of the ship, and extensive hatches and enormous air ports or doors wherever possible. To prepare for cold weather service ample heating facilities should be installed.

In the living quarters the question of space and ventilation should be thoroughly studied. As it is simply a question of making the ship big enough, there should be no trouble on this score. In the shops there should be doors readily opened and readily secured watertight, but practically making the upper part of the walls of the workshops entirely open. Doors should be arranged to swing on horizontal hinges, and should be at least four feet deep in a vertical direction, and it should be possible to secure these doors at whatever angle advisable, thus making a side awning of metal against sun and rain. Above the boiler and blacksmith shops overhead doors, easily handled, should be arranged, so that at least two-thirds of the deck overhead could

be open. Above this again should be spread awnings heavy enough to keep out the rays of the sun and to protect against rain. Hatches, at least 20 feet by 12 feet, should be practically continuous along the center line of the ship and throughout the length of the work shops and store spaces, so that there would be every opportunity for proper ventilation.

In the crew and workmen's quarters there should be as many large, square ports as is possible consistent with the structural strength of the ship.

The most approved ventilating system should be adopted, and a great quantity of electric fans provided for circulating the air.

Standees.—The crew and workmen should all have standees for sleeping, and the most approved comforts for messing.

Washing.—The washing arrangements should be most complete and extensive, with an ample supply of fresh water at all times, and no washing whatever should be done in salt water.

Gravity Tank.—There should be a gravity tank on the highest deck, with an automatic arrangement, so that it would be constantly filled with fresh water, and pipes should run from this tank to the various washrooms, galley, pantries, officers' rooms, etc. The washrooms should be arranged so that the men could do their washing and keep their clothes in their own part of the ship. As far as possible with cleanliness, there should be different washrooms and lockers for the different shops, so that all the workmen could keep their effects in the neighborhood of their work.

Lockers.—The lockers should all be of the approved open-work, Navy type; those for the workmen should be arranged so that their citizen's clothes could be kept in good condition, and these men should have considerably more locker space than is allotted to the crew.

GENERAL PLAN OF SHIP.

The ship should be of at least ten thousand tons displacement; at least sixty feet wide, and should have a draught of not more than twenty feet at the load-water line. This would make her

stable in all conditions, and would allow her to go into all harbors of any importance. She should be of the prevailing freight-carrying type of merchant vessel, with high structure amidships and raised forecastle and poop. Her motive machinery should be in the middle of the ship. She should have a single-screw engine of the simplest type for long distance steaming. At about three feet above the load-water line the berth deck should extend the entire length of the ship, leaving a space for the fire-room and engine-room trunks where necessary. The entire space under this deck should be given up to motive machinery and power plant, coal, oil and storerooms. The berth-deck space should be at least nine feet high, and should extend the entire length of the ship, and should be used almost entirely for berthing space. She should have a main deck above the berth deck for the shops, corresponding with the spar deck of an ordinary ship; it should be decked over with a light deck fore and aft, with shallow beams overhead. The part aft of the engine-room trunk should be used for the machine shop. In the wake of the engine and boiler trunks should be the wood-working shops, ordnance shop, electric shop and other small shops. The foundry should be over the boilers. Forward of the engine and boiler trunks should be the boiler, blacksmith and coppersmith shops. Above the foundry there should be an extensive opening in the deck to allow the escape of heat, dust, etc., especially when dropping the cupola. Above the machine shop there should be large ventilating hatches along the middle line of the ship. Above the blacksmith shop and boiler shop there should be extremely large ventilating hatches along the middle line of the ship, with extra hatches over the fires and with awnings above all, to allow the escape of smoke, gases, etc. If oil forges should be used, as would be likely to be the case, there would be less smoke, but the ventilation would still be required.

The officers' quarters should be aft on the deck above the spar deck under the raised poop. The details of the necessary rooms for warrant officers and foremen, pay office, sick bay, etc., would have to be worked out by the designing constructor to the best advantage.

GENERAL ARRANGEMENT OF MACHINERY.

Great care should be exercised in arranging the position of all the machinery so that the heat could be kept entirely in one part of the ship. The boilers, main engine and auxiliaries, and all steam-driven machinery should be enclosed up to the height of the berth deck with vertical bulkheads of double thickness with air spaces between. One of these bulkheads at each end of this space should be of light material for a screen; the other watertight as usual. Thus the heat would be enclosed as much as possible within these vertical walls, and would be allowed to escape up large hatches and leave the rest of the ship as cool as possible.

It would be preferable to have all this heat aft in the ship, as in the lake carriers, but it would be impossible to arrange weights for this purpose, as all weights on board except the hull, etc., would be of a shifting character, even to the water ballast, as the exigencies of the service might require that all the fresh water, even to that in the forward ballast tanks, should be pumped out for the use of boilers of ships at one time. This would cause such a slope of the decks that it would not be possible to do proper work in some of the shops, for instance, the foundry and blacksmith shops. This arrangement of having the motive and other machinery aft would be of great advantage, leaving open, free decks, etc., but would have to be given up for the reason stated.

Position of Machinery.—Thus, the machinery should be in the center of the ship longitudinally, and all steam-driven, and thus heat-producing, machinery should be arranged to the best advantage there. It should also be arranged so that as few men as possible would be on watch at one time, and these few men should be able to care for different types of machines.

Boiler Plant.—The boiler plant should be of the simplest kind, so that it could be in constant use without repairs and would require the least amount of attention under way and in port.

Oil Fuel.—As the question of the use of oil for steaming is being rapidly and conclusively solved by the Board of Officers

from the Bureau of Steam Engineering, oil fuel should be used on the repair ship.

The furnaces should be designed so that coal could be burned by making few changes, in case the oil supply should fail from loss or capture of the oil-supply steamers.

Engines and Auxiliaries.—The main engine should be of simple type, long stroke and ample bearings, so that it could run indefinitely without repairs. The auxiliaries in the engine room should be ample, with duplication of duties, to prevent possible entire stoppage of any type of duty.

All the steam-driven machinery should be within the double vertical bulkheads, and there should be no entrance to the spaces for these machines except from the engine room, so that no heat whatever could pass to other parts of the ship.

The boilers should be athwartship, and should take up the entire width of the ship, if feasible. The main engine would use only a comparatively narrow part of the beam, and there would be ample space on either side for most of the other machinery.

Dynamos, Etc.—The dynamos should be on one side of the engine room, and the floor of the dynamo room should be on a level with the floor plates of the main engine, and with a low partition, three or four feet high, between them and the main engine, to keep out oil, water, etc. The pneumatic pumps for supplying torpedoes, the lower-pressure pneumatic pump for power to be used on board, and the hydraulic pump, should be in this same compartment, so that one attendant could care for them all.

Evaporators.—The evaporators should be on the other side of the main engine, in a partially partitioned-off space, and with the floor of the room on a level with the main engine floor plates. The condensers or distillers for the evaporators should be high up on the inside of the engine-room hatch, so that the condensed steam could drop as far as possible through air on its way to the tanks just above the level of the evaporators. One attendant could take care of all these evaporators.

As these dynamos, etc., on one side and the evaporators on the

other would take up a greater longitudinal length than the main engine, the main condenser should be placed forward or aft of the main engine.

Ice Machines.—The ice machines should be forward of the boilers on the level of the berth deck, and should be within the vertical double bulkheads with ample hatches above. One attendant could take care of the entire plant.

Galley.—The galley should be placed above the machinery spaces, so that even this heat would be centered with the rest.

Foundry.—The cupola and brass furnaces, as well as the drying ovens for cores, should be above the main boilers, so that this heat would be also retained in the heat space.

Trunks.—From the level of the berth deck upwards the boiler and machinery spaces should be confined by trunks of ample width, so that the decks would be clear on both sides for free circulation of air.

Shield Deck.—Just under the berth deck throughout the engine and boiler space there should be a light shield deck with air space, so that the heat from below could not penetrate to this deck. This air space should have connections to ventilators for discharge of heated air.

The side walls of the machinery space above the berth deck should be double walled, with connection to ventilators, leaving an air space. No steam pipes whatever, except for steam heaters and for the galley, should be led outside the machinery spaces.

Heat.—Thus all the heat would be included in one part of the ship, and all machinery outside of this space should be run by electricity or compressed air, as found advisable.

POWER.

There should be boiler power sufficient to drive the ship at and to readily maintain a speed of sixteen knots under natural draft, and to run the necessary auxiliaries, including lights, etc. The closed fire-room system of forced draft should be used, the blowers being in the engine room.

As little repair work would be done under way, the power

proper for driving the ship would be ample for all purposes. In port there would thus be ample power for the following :

1. The regular port detail work carried on by steam power, heating the ship, running evaporators, etc.

2. Electric plant for lighting the ship, running ventilating fans, searchlights, electric cranes, individual machines, windlass, steering engines, blowers, etc.

3. Pneumatic plant for charging torpedoes.

4. Pneumatic plant of about 100 pounds pressure, for lifts, chippers, calkers, drills, power steam hammer, etc., and for burning oil.

5. Hydraulic plant of small capacity for a pressure of at least 2,000 pounds per square inch, with reducing valves, for testing hydraulic pipe, boilers, etc., and for use in heavy welding, forcing parts of machinery together, bending pipes, etc.

Motive Power.—As the duty of the repair ship would be such that there would seldom or never be need of extreme hurry in getting under way, and as the question of weight of machinery need not be considered, as in the case of men-of-war, the boilers and main engine should be designed for long, continuous service without repairs and extremely careful attention, nor need the question of the utmost fuel economy be a primary factor in the design.

Boilers.—For the purpose, then, there seems to be no question but that the Scotch or tank boiler is best suited. The boilers should be double-ended, return-tubular, of the prevailing Navy type, designed for a pressure of about 160 pounds above the atmosphere. Great care should be taken to so design them that they could be kept in order with the least trouble, especially leaving plenty of space for getting at all parts of the boilers, inside and out, for scaling and cleaning.

Main Engine.—The main engine should be of the vertical, inverted, three or four-expansion stage type, and should be of the simplest character, with little regard to weight. It should have a long stroke and very large bearing surfaces, so as to run indefinitely. The type of engine so successful in our merchant marine for long-distance steaming should be used.

Plenty of spare parts should be carried, so that the repair ship

should never be in need of repairs, and could keep with the fleet until it should become necessary to dock the ship. With the facilities on board and the large part of the time spent in harbor, there should be no need of ever doing work ashore on the machinery of the ship, except in case of a serious breakdown or when new boilers would be required.

Oil Fuel.—Oil fuel should be burned by the compressed-air method, so that there would be no loss of the fresh water that is so precious to the fleet in war times.

Auxiliary Pumps.—The auxiliary pumps should be all of one type for the various purposes, and many spare parts should be carried, so that no part of the work of the ship could be out of operation. Each part of the work should be handled by two auxiliaries, and each of these auxiliaries should be able to handle it all when necessary, thus insuring a certain action.

Electric Plant.—The electric plant should be designed so that there would always be one spare dynamo when all the required work is being done. They should be of the approved voltage for the Navy, and should be of the Navy type of machine. There should always be power available for the following purposes:

Lighting the ship.

Searchlights, four in number.

Signal lights, Ardois and blinker.

Lighting ships alongside, if necessary.

Ventilating fans for constant use, and for special use in hot weather.

Electric cranes, each to lift at least ten tons, twelve in number, though never more than four would be likely to be in operation at the same time, and the usual lift would be light.

Machines of the repair plant.

Blowers for the cupola.

Blowers for the forges of blacksmith shop, boiler shop, coppersmith shop, etc.

Windlass.

Steering engine.

Ammunition hoists for battery on board.

Coal carrier for supplying coal to torpedo boats, etc.

Any other machines outside of the machinery space.

Their position in the engine room would allow of the most economical use of steam, and the steam would be taken by short, separate pipes from the boilers. The condensers would be near by and a good vacuum would be secured. The low partition between these machines and the main engine should be arranged to be quickly removable, so that an armature or other part out of order could be hoisted up the hatch and carried to the electrical room or the machine shop for repairs. By having them in the same room, besides keeping the heat away from the rest of the ship, the ventilation would be good, as they would be in the engine-room space and there would be no close deck overhead to keep the heat closed in. The heat would rise with the ascending current from the main engines.

The dynamos should be in charge of the engineer officer of the ship, thus avoiding complications and giving a greater opportunity for arranging the force of men to advantage. The storerooms would then be in one, and one storeroom keeper could issue for the dynamo necessities as well as for the main engine.

The dirt from the dynamo room would thus be added to that of the engine room and one cleaning would do for both. Also, there is no question but that the dynamos would be better cared for under the eye of the skilled engineer than under directions of the officer with the usual cursory knowledge of the subject, who would have to leave the practical part of it to an enlisted man of uncertain type.

The wires for the currents should be carried by the approved methods to whatever points necessary. There should be connections on deck for attaching heavy mains for lighting up a ship alongside when her electric plant is disabled or for lighting up repair work on a ship having no electric-light plant.

Pneumatic Pump for Torpedoes.—The pneumatic pump for charging torpedoes should be of the approved design, with storage tanks or batteries of considerable capacity. As this ship would be a tender for torpedo boats, there should be enough capacity in the storage battery so that two torpedo boats could come alongside and charge their torpedoes at once, and be ready

for immediate service. There should be at least two pipe connections at convenient places on both sides of the ship, with long connecting pipes, ready, so that torpedoes could be charged from both sides of the repair ship and at both ends of the torpedo boats at once. The pressure carried in the battery of compressed air should be sufficiently above that used in the torpedoes so that four torpedoes could be charged at once without reducing the pressure below the necessary amount.

A branch pipe should lead to the ordnance work room, for test work on torpedoes being repaired there.

Pneumatic Pump for Shops.—The pneumatic pump for supplying air for the use of air tools on the repair ship should be one of the slow-running types in the market. The capacity of the pump should be about 300 cubic feet of air per minute, and the tank should hold at least 2,000 cubic feet. The pressure should be 100 pounds per square inch. From the tank there should be one metal main of 2 inches diameter, extending forward and aft. From this main as many branches of metal pipe should be led as found necessary to supply the various tools in the different shops, and varying lengths of air hose should be available at these points. Besides these lines of metal pipes there should be additional main metal lines of pipes of 1 inch diameter leading from the 2-inch main to the side of the ship, two forward and two aft on either side, for 1-inch hose connections for mains to be carried to ships alongside. These hose should connect with movable manifolds with at least four valves each, so that four different tools could be in operation at the same time from each line of pipe. The intention of these lines would be to do calking, riveting, drilling, scaling, etc., on the hulls of ships inside and out, and to scale boilers.

A special 1-inch metal main should be led for the use of the engine and fire rooms, with suitable valves, hose, etc., for use in overhauling machinery and scaling boilers, etc.

Hydraulic Pump.—The hydraulic pump should be one of the approved types in the market, with an accumulator of considerable capacity, where the pressure would be maintained by steam pressure on a large piston transmitted to a smaller piston over

the water. This would be used only occasionally, but would be invaluable when needed. It would be used for testing pipe, common and hydraulic; boilers under repair; heavy welding; forcing parts of machinery together, as bushings, crank pins, etc.; bending pipes; etc.

Reducing valves easily set by outside screws would be a necessary part of this plant. As this power would only be used in one or two places on board, the piping system would not be very extensive.

COAL AND COALING.

Bunker Capacity.—The coal bunker capacity should be at least five hundred tons, to allow for emergency of non-delivery of oil for steaming purposes, and for supplying torpedo boats when colliers are not available. There should be especially large coaling trunks, so that little stowing of coal would be required in the bunkers. There should be adjustable electrically-driven coal carriers that could be dropped into coal chutes, so that coal from the bunkers could be shoveled into these carriers and discharged over the ship's side into the chutes leading down to the decks of torpedo boats and other small craft alongside the floats on the side of the ship. These carriers could also be used for supplying coal to the steam launches and to the galley of the repair ship. They should be controlled by a man at the ship's side, so that the speed could be regulated as necessary. They should be arranged so that the operation could be reversed, and so that coal could be transferred from the hold of a ship alongside into the bunkers of the repair ship. These operations would require adjustable lengths of carriers and supports for the frame, all of which should be arranged so that changes could be made in the most expeditious manner. The operation of coaling the repair ship and of coaling ships from the repair ship would consist simply of men shoveling the coal into the carrier on one ship and freeing the discharge of the carrier on the other ship.

Coaling at Sea.—There should be the most approved form for coaling at sea, so that the repair ship could either be towed by a

man-of-war or could tow small craft astern, or both at the same time, and so that coaling could be carried on rapidly in any moderate weather. It should also be possible for the repair ship to be secured alongside a man-of-war, or between two men-of-war, and carry on the coaling rapidly under way with the coaling carriers. For this purpose very large elastic fenders should be carried on board the repair ship, so that the ships could be separated to a distance of six feet. There should be sufficient labor available, so that the work of coaling could be pushed to the utmost, both as regards quantity and speed.

Hard Coal, Coke, Etc.—The space above the evaporators and dynamos, and between those and the berth deck, should be utilized for carrying blacksmith coal, coke, charcoal, molding sand, fire sand, fire brick, anthracite coal, etc., in bulk.

OIL FOR STEAMING PURPOSES.

Capacity of Tanks.—There should be sufficient tank capacity for double the quantity of oil necessary to drive the repair ship at its full natural-draft speed for a distance of fifteen thousand miles. This would allow the ship to travel to any port of the world and to remain there for a period of six months or more, and return to the place of starting, with no additional supply of oil.

Oil Supply to Ships.—This would also allow an ample supply of oil for furnishing torpedo boats and other small craft, which surely will be burning oil before long. As it is likely that oil will be burned on larger ships, the repair ship would be able to even furnish the larger ships with oil on occasions, in case of loss or capture of oil-supply steamers. There should be pumps in the repair ship, of large capacity, for furnishing oil to other ships. These pumps should be connected with manifolds on the highest deck by pipes at least 4 inches in diameter. The regular standard hose connections should be made to these manifolds, so that special lengths of hose could be reserved and used to supply other ships with oil. These lengths of hose should be sufficient in number so that at least two ships, each one a quar-

ter of a mile away from the repair ship, could be supplied at the same time with steaming oil. The manifolds should have sufficient valves so that at least four streams of oil could be running at the same time to ships alongside or near the repair ship.

Oil Supply at Sea.—The oil hose should be arranged to carry a supply of oil to other ships while under way, as in the case of coaling.

Filling Tanks.—The oil tanks of the repair ship should be filled from oil-supply steamers in the most rapid manner. Arrangements should be made for connecting the suctions of the large oil-handling pumps of the repair ship with the holds of the oil steamers, the discharges connecting with the ship's tanks. This should be in addition to the usual connections made with the pumps on the oil steamers, so that there may be the least possible delay in supplying the repair ship with steaming oil.

Storage of Oil.—The oil should be stowed in properly designed tanks, not a part of the structure of the ship. These tanks should be built and inspected with the utmost care, to prevent leakage. It should be possible to inspect the outside of these tanks at any time, so that the least leak may be quickly discovered and stopped. They should be designed so that they would not be caused to leak by the grounding of the ship, or by any ordinary catastrophe.

Ventilation of Tanks.—Ventilation of the most approved form should be fitted, and ventilating pipes should be led so that their outlets would be well away from any possibility of danger.

Pipes to Tanks.—The pipes from the oil tanks supplying the boilers and manifolds and for supplying other ships should be most carefully constructed and inspected, and should be open to inspection at all times, so that leaks could be at once discovered.

Position of Tanks.—As the oil may be readily led to the boilers from any position in the ship, it is more important to place the coal bunkers than the oil tanks near the fire rooms. This could be arranged as seems advisable, either placing the large bunkers between the batteries of the boilers, or placing the bunkers forward and aft of the boilers, placed back to back. The oil tanks could then be placed under the ice machines forward of the boilers or bunkers.

FRESH WATER.

Evaporators.—The best type of evaporator for the purpose known at present is the Navy type. The battery should consist of twelve 4,000-gallon evaporators of the latest Navy design. Each of these would be capable of supplying at least 3,500 gallons per day in the tropics, making 42,000 gallons the output under the worst conditions. Allowing 2,000 gallons per day for the use of the repair ship and for time lost while scaling evaporators and for possible overhauling, it is certain that it may be possible to count on a gain of 40,000 gallons daily for the double bottoms and tanks for storage. It would take at this rate 12½ days to entirely fill the storage tanks if nothing were taken from them. As these would hold enough water for over forty of the largest tank boilers, it would seem that there were enough capacity in the evaporators.

A complete set of travelers should be arranged for carrying the evaporator coils to the most convenient position for scaling, so that this operation could be accomplished in the least possible time. The low screens between the evaporating plant and the engine rooms should be easily removable for this purpose.

Distillers.—To condense the steam from these evaporators there would be required twenty condensers or distillers of the aerating condenser type in use in the Navy, each with a capacity for 2,500 gallons. These should be arranged in a battery at the top of the engine-room hatch inside, and should be placed vertically. A system of valves should allow cutting out any one of the distillers for overhauling, if necessary, by closing off any sets of valves in the cooling and discharge lines.

The condensed water from the distillers should be allowed to drop through the air as far as possible into a large tank as low down in the engine room as could be arranged while allowing men to pass below.

During the drop of this water it should be broken up by falling through many perforated plates with small holes in them. Thus the water would be still more aerated.

This tank should be allowed to nearly fill with water. It

should then be tested before being pumped to storage tanks, to insure its potability.

Pumps used for no other purpose should discharge this water into proper tanks and double bottoms. Water should be used in different double bottoms in succession for drinking purposes, thus giving the longest possible time for the water to become sweet and good for drinking.

Water Supply to Other Ships.—For supplying fresh water to other ships pumps should be used that are not connected for any purpose but for fresh water. Discharge pipes, at least four inches in diameter, from these pumps should connect with manifolds on the spar deck. To these manifolds Navy-standard hose should be connected and lengths of hose attached, so that water could be pumped to any ship within a radius of half a mile, the hose being supported by specially designed and easily attached buoys at the couplings. In this way the drinking tanks and boilers of any ship could be quickly supplied with water. If a ship could come alongside, four or more streams could be used.

Many couplings should be carried on board the repair ship, for joining with all sorts of male and female connections found on ships in the Navy and merchantmen, so that the hose could be screwed to the usual hose connections for filling boilers or ship's tanks.

Fresh-Water Tanks and Double Bottoms.—There should be double bottoms throughout the entire length of the ship. These should be divided up to conform with the watertight bulkheads. Forward and aft there should be trimming tanks of large capacity, arranged also for carrying distilled water. One double bottom under the engines or boilers should be used for a reserve-feed tank and for no other purpose. The overflow from the hot well and the drains from the steam cylinders of pumps, traps, etc., should connect with this double bottom.

There should be automatic electrical devices in these double bottoms to show in the engine room the height of the water at all times. Besides these, regular sounding wells for the double bottoms should be installed.

Gravity Tank.—There should be a distributing tank of a

capacity of at least 2,000 gallons on the highest deck amidships with pipes leading to officers' quarters, galley, pantries, washrooms, scuttle butt, etc. This tank should have automatic electrical devices, causing a bell to be rung in the engine room whenever the water is below or above a certain level.

Direct Distilling.—There should be a connection with the main boilers by special piping, so that steam could be led directly from the boilers to the distillers without passing through the auxiliary steam lines, which would be more or less coated with oil, so that steam could be condensed directly from the boilers when the ship is lying in fresh water. There should also be a connection so that steam for make-up could be led from the evaporators to the low-pressure receiver or feed tank, or to the double bottoms used as a reserve tank. The pipes for leading steam to the feed tank and to the double-bottom feed tank should be led down near the bottom and should be fitted with mufflers.

STORES.

The paymaster should have charge of all the stores on board other than those required for the different departments of the repair ship proper. There should be carried a large quantity of supplies for use of the other ships in the fleet. This list should be made out by the different bureaus, and there should be sufficient material of each kind to last the squadron for at least six months. Ample, well-ventilated and well-lighted store rooms should be provided, and the hatches so arranged that stores could be dropped into place and brought up from the holds with great rapidity by the lifts. Besides the stores for general issue to ships there should be a special list of material and tools for the use of the repair ship only, so that at no time could the repair ship be crippled on account of lack of material or tools. These repair-ship stores should be kept in separate store rooms, so that dependence would not be placed on lists of stores, but that the actual stores would be there and ready for use of the repair ship at all times.

As material would be required for immediate work, there should be a system of simple stub requisitions, so that necessary

material could be immediately available from the stores on board in charge of the paymaster. It should not be necessary to have these requisitions signed by any one except the engineer officer or the outside or inside master mechanic, as the delay that would be caused by waiting for the various signatures of the commanding officer and paymaster would materially interfere with the serviceability of the repair ship. The stores should be taken out of their boxes or wrappings, and should be arranged so that any article on board would be available at very short notice; and there should be an ample force of men ready at all times to break out material from the holds and store rooms and to hoist it on deck and to distribute it where necessary in the quickest possible time. Every week there should be checked up the amount of material of all kinds on board for use of the repair ship, so that requisitions could be made out in ample time for the new material. This would require a large clerical force in the paymaster's department.

SHOPS.

There should be on board the following types of shops:

Machine shop.	Ordnance shop.
Boiler shop	Electrical shop.
Blacksmith shop.	Divers' shop.
Foundry.	Paint shop.
Coppersmith shop.	Rope shop.
Pattern shop.	Sailmakers' shop.
Plumbers' shop.	Carpenter shop.
Shipwright shop.	Clerical force.

The following is a proposed list of machine tools, etc., to be installed in the various shops.

Machine Shop.—

1 electric motor, about 60 H.P., for driving machinery.

1 electric motor, spare, for same.

1 lathe, 3-foot swing, 7 feet between centers.

1 two-spindle lathe, 24 inches by 40 inches swing, 10 feet between centers.

2 lathes, 24-inch swing, 14-foot bed.
3 lathes, 18-inch swing, 4 feet 6 inches between centers.
3 lathes, 12-inch swing, 6-foot bed.
2 lathes, 14-inch swing, turret.
1 lathe, 10-inch swing, hand speed.
2 lathes, toolmakers'.
1 planer, 48 inches by 48 inches, to plane 8 feet.
1 planer, 36 inches by 36 inches, to plane 6 feet.
1 shaper, compound, 16-inch stroke, 6-foot bed.
1 shaper, 14-inch stroke.
2 shapers, small.
2 shapers, pillar, 12-inch stroke.
1 universal milling machine.
1 plain milling machine.
1 radial drill press, 36-inch.
2 drill presses.
1 drill press, sensitive.
1 key-seating machine.
1 metal band saw.
1 metal saw, circular.
2 pipe-threading machines, power.
2 sets pipe-threading machines, hand.
1 bolt cutter.
1 tool grinder, wet wheel.
1 emery tool grinder, 2 wheels.
1 twist drill grinder.
1 plane table, 4 feet by 6 feet.
Vises, surface plates, etc.

Boiler Shop.—

2 fixed forges, 48 inches square.
1 combination punch and shears.
1 hand-power bending rolls, 6 feet long.
1 flange clamps.
1 flange block.
2 portable forges, small.
1 portable heater, oil, for crown sheets, etc.
2 anvils.

4 bending blocks, boiler-tube.
1 rotary hand shears.
1 hand pump, for testing boilers.
6 vises.

Blacksmith Shop.—

3 fixed forges, 48 inches square.
3 portable forges.
1 bolt header.
1 swage block.
6 anvils.
1 blacksmith mandrel.
1 steam hammer, 600 pounds.
1 cast-iron cone.
1 oil-tempering tank.
Vises, etc.

Foundry.—

1 cupola, 2,000 pounds capacity.
4 brass furnaces, 600 pounds total capacity.
1 core oven.
Flasks, bench-working machines, etc.

Coppersmith Shop.—

1 forge.
1 bending table.
1 planishing table.
Coppersmiths' stakes of all kinds, vises, etc.

Pattern Shop.—

1 band saw.
1 buzz planer.
1 bench trimmer.
2 bench vises.

Plumber Shop.—Pipe vises, and all necessary hand tools.

Shipwright Shop.—Necessary hand tools in connection with pattern shop.

Ordnance Shop.—

1 lathe, 18-inch swing by 12-foot bed.
1 14-inch shaper, complete.
1 No. 1 upright drill, 18-inch table.

1 universal milling machine.

1 air compressor. (This in dynamo room.)

Complete sets of special tools for ordnance work.

Electric Shop.—Necessary hand tools. The machine tools of machine shop to be used.

Divers' Shop.—2 complete diving suits, pumps, etc., spare parts, etc.

Paint Shop.—Ordinary painting outfit.

Rope Shop.—Vises, clamps and necessary outfit for doing repairs both for ordinary rope and wire rope. Apparatus for repairing wire cables, grappling irons, etc., for cables.

Sailmakers' Shop.—Benches, sewing machines, etc., required.

Carpenter Shop.—Benches, hand tools, etc., with use of tools in pattern shop.

Clerical Force.—Desks, typewriters, etc.

In all these various shops there must be every possible tool and appliance than can be used with the various machines, with plenty of spare parts and spare tools. There should be also ample outfits of the various tools in all shops for hand work, arranged in kits, to be carried on board other ships, and for use on board the repair ship.

The following is a list of some of the devices and materials that are somewhat unusual, and might be forgotten in making up a list of tools and materials for a repair ship:

Chain tongs for large pipe.

Surface plates.

Tags and tagboards for drawing out tools from tool room.

Revolution counters with watch attachments.

Valve reseating machines.

Parts of mechanical telegraph.

High-pressure hydraulic pipes, all sizes.

Jacks, hydraulic, heavy power, for crown sheets.

Test pumps for steam and vacuum gauges.

Test pump for boilers, hand.

Cutting tools to be of material for the deepest cuts.

Chests for different shops for kits of tools.

Boxes for fire clay and other dusty material.

Beam clamps.
Forcing bolts of all sizes.
Slings, manila and wire.
Towels, ample for working force.
Tally registers.
Scales, platform and hanging.
Apparatus ready for rapidly white metalling bearings.
Bronzes of all kinds and sizes, round, hexagonal, octagonal.
Spring wire, bronze and steel.
Brass tubing for condenser ferules. Combined drills and taps for all sizes of ferules.
Plaster of Paris.
Bolts and nuts of all material and sizes.
Rivets, ditto.
Formers for hydraulic valves.
Leather, sheepskins.
Sets of springs for all types and sizes of pumps. Formers for springs ready to be screwed on mandrels of lathes.
Left-hand ratchets.
Boring bars.
Air tools.
Portable heater, oil, for burning off paint, heating hull plates, crown sheets, etc.
Flue or tube-hole cutters, adjustable.
Rotary hand blowers.
Beading, burring, turning and wiring machines for coppersmith shop.
Gasoline fire pots.
Micrometer calipers.
Brands for marking handles.
Strong backs for straightening tube sheets.
Tube expanders with gear for lower drums, torpedo boats.
Alphabets.
Firing tools, sets for ships, torpedo boats and launches.
Trucks, ordinary freight, for handling material.
Trucks, flat top, for plates.
Rotary shears.

Electrical coppersmith irons, flat irons and cooking devices.

Bending blocks and appurtenances for bending torpedo-boat boiler tubes.

Spare plugs, all sizes, for torpedo-boat boiler tubes, slight taper, slight thread on taper, and turning tappet on end.

Rigging for quickly testing valves of pumps by hydraulic power.

Tools for condenser-tube packing.

Condenser-tube expanders and boot tools.

Tube cutters.

Polished drill rods for small rods and valve stems.

Zincs for boilers.

Ice-machine fittings.

Printed tags for repair work.

Rubber stamps.

A complete list of proposed tools and material has been sent to the Bureau of Steam Engineering for record.

TOOL ROOM.

The tool room should be centrally located and easily accessible to all the shops, and should be fitted with approved racks, shelves and drawers for the various implements required. A system of tags should be arranged so that each man could be charged with and held responsible for every tool that he would draw. In connection with the tool room there should be a small store room where small quantities of the most used articles could be stowed in racks, shelves and drawers, with complete weighing facilities and measuring devices, so that there would be no delay in serving out these stores as required. The toolmaker, with as many assistants as necessary, should be constantly at work keeping the tools in proper order, and should be held responsible for an ample supply of tools ready at all times for quick delivery to the workmen.

PERSONNEL.

The ship's force proper should be entirely distinct from the repair and supply force, and should have separate quarters.

Their duties should be absolutely separate. This force should be enlisted as a part of the regular Navy. Their work should be to care for the ship; to run steam launches, boats for working parties, etc.; to handle stores and repair material into the ship and out of the ship.

The repair force should consist of men enlisted for special service, and they should be paid by the month. Their physical examination should be less stringent than that for the regular service, with the proviso that those who have physical disabilities waived could make no claim on the Government on account of those disabilities. It should be possible to discharge these men, if incompetent, at any time, returning them, of course, to the United States. It should be possible to promote or reduce them in rating at once, as found necessary.

As repair work would be very irregular, it should be distinctly understood that these men of the repair force would be required to work with the utmost speed and enthusiasm when necessary, working day and night cheerfully. When there would be no rush of work these men would have little to do beyond keeping the shops in repair and making necessary tools and assisting at experimental work. This would be a rather expensive operation, but in no other way could this important work be accomplished. These men should be first-class mechanics in their several branches, and should receive the highest rates of pay given in the United States for their respective trades, and should receive a Navy ration in addition. If necessary, in order to acquire the best men, these rates of pay should be still further increased. These men should not be required to wear uniform, and should be treated with great consideration. They certainly should not be required to pass around the mast at Sunday inspection. They should, however, be subject in all respects to Navy discipline. The foremen should be special men with special rates of pay, and should be treated as, and mess with, the warrant officers.

These men of the repair force should have a certain portion of the ship reserved for themselves, so that they would not be required to mess with the regular crew or to associate with them.

They should be given every reasonable opportunity to visit the shore in the various countries visited, so that they would be interested and would be likely to remain on the repair ship instead of trying to get their discharges.

As the success of the repair ship would depend almost entirely on the willingness and enthusiasm of the repair force, life should be made as pleasant for them as possible, so that when work should come they would do their utmost to rush it through.

The following is a proposed list of the repair-ship personnel:

Machine Shop.—1 master mechanic, outside; 1 master mechanic, inside; 1 toolmaker; 10 machinists, 1st class, tool hands; 10 machinists, 2d class, tool hands; 10 machinists, 1st class, all round; 10 machinists, 2d class, all round; 20 helpers, 1st class.

Boiler Shop.—1 quarterman; 1 flange turner; 20 boilermakers, 1st class; 10 helpers; 20 rivet heaters, small boys, used for scaling boilers also.

Blacksmith Shop.—1 leadingman; 8 blacksmiths, 1st class; 8 helpers, 1st class.

Foundry.—1 quarterman; 4 molders; 4 helpers; 1 cupola tender.

Coppersmith Shop.—1 quarterman; 2 coppersmiths, 1st class; 1 coppersmith, second class; 2 helpers,

Pattern Shop.—1 leadingman; 1 patternmaker, 1st class; 1 joiner, second class.

Plumber Shop.—1 leadingman; 2 plumbers; 2 pipe fitters; 2 helpers.

Shipwright Shop.—1 leadingman; 4 shipwrights.

Ordnance Shop.—2 ordnance machinists, all round; 2 ordnance machinists, tool hands; 2 machinists, torpedo.

Electric Shop.—2 machinists, electrical; 2 linemen; 2 helpers.

Divers' Shop.—2 divers; 4 helpers.

Paint Shop.—1 painter, 1st class; 1 helper.

Rope Shop.—1 rigger; 1 helper; 1 wire-rope rigger; 1 helper.

Sailmakers' Shop.—2 sailmakers; 2 helpers.

Carpenter Shop.—2 carpenters, 1st class; 2 carpenters, second class.

Clerical Force.—1 clerk; 1 storekeeper; 1 writer.

Pay.—At the present rates of pay, it is estimated that the pay alone per month of these mechanics would be in the neighborhood of $15,000.

Outside Master Mechanic.—The outside master mechanic should have general direction of all work done outside of the ship, and should be held responsible for quick and accurate completion of all repairs in all branches. He should accompany the working forces that leave the ship, and should see that they are distributed throughout the ships under repair, and should also see that they return on board the repair ship at meal times and when the work is completed. Under the outside foremen, the quartermen and leadingmen of the different technical branches should have charge of their own forces, and should oversee the work on the different ships. If there should not be a sufficient number of quartermen and leadingmen for the number of ships under repair, one man of each squad should act as leadingman, and should be held responsible that the work is carried on properly. At the end of each day the quartermen and leadingmen should report to the outside master mechanic, on forms provided for that purpose, and verbally, the condition of the repair work on each ship, and should give him a list of the number of men and material required for the next day's work. The outside mechanic should submit these lists to the engineer officer, and orders for the next day should then be given, so that all the men would be ready on time and the material in the boats, and so that there would be no delay in starting off for the repair work. The crew of the ship should run all boats for moving men and material for repair work, and there should be no delay in having these boats ready and the workingmen mustered in the gangway on time. It is extremely important that these workingmen out of the ship on repair work should be brought on board promptly at meal hours, and that they be given ample time during and after meals for a complete rest.

Inside Master Mechanic.—The inside master mechanic should have charge and be responsible for all repair work done on board the repair ship. He should receive the work when it is brought on board, together with the engineer officer, and, after a record

of it is made by the clerical force, should distribute the work to the various shops, and follow it up, so that it may be accomplished in the most accurate and rapid manner, and should deliver it to the engineer officer upon its completion, so that a record may again be taken by the clerical force and the work returned to the ship whence it came. He should have charge of all the various shops and should have particular charge of the machine shop, where the bulk of the work would be done.

Quartermen.—The quartermen and leadingmen of the various shops should be held responsible to the inside master mechanic for the prompt and efficient completion of work given them. They should have charge of their various shops, and should arrange the work to the best advantage. At the end of each day they should report to the inside master mechanic, on forms provided for that purpose, and verbally, the condition of each article being repaired, and directions should be given by the inside master mechanic, subject to the approval of the engineer officer, for the next day's work.

Drawing Stores.—The master mechanics, quartermen and leading men should be authorized to draw from the tool rooms and store rooms the tools and stores that may be necessary for the carrying on of the different articles of work. The tools, however, should be charged to the individual workmen and not to the foremen and leadingmen. The material, of course, would be charged to the work being done.

Records.—When a piece of work is brought on board and the repair is authorized, a record should be taken by the clerical force and a job-order number given to each portion of the work. Simple job orders should be made out by the clerical force and signed in pencil by the master mechanics and sent to the different quartermen and leadingmen. Upon the arrival of each piece of work there should be a printed tag attached, with spaces for the name of the ship, the bureau concerned, the date of the receipt of the article, the job-order number, the cost of the labor and material, the date of completion and the date of delivery. The quartermen and leadingmen of the various shops should keep a daily record of the labor and material expended on each job order,

and the card system should be kept in the office for tabulating these various reports sent in daily, so that at any time the total cost of repair of each article could be known up to the end of the previous working day. Then, when the job order is completed, the card would show the full totals from the time of the receipt of the article to the date of delivery, and would give the cost of labor and materials. These amounts could be charged to the various ships and bureaus concerned and the costs of repairs on the different ships summarized.

REPAIR WORK OUTSIDE OF REPAIR SHIP.

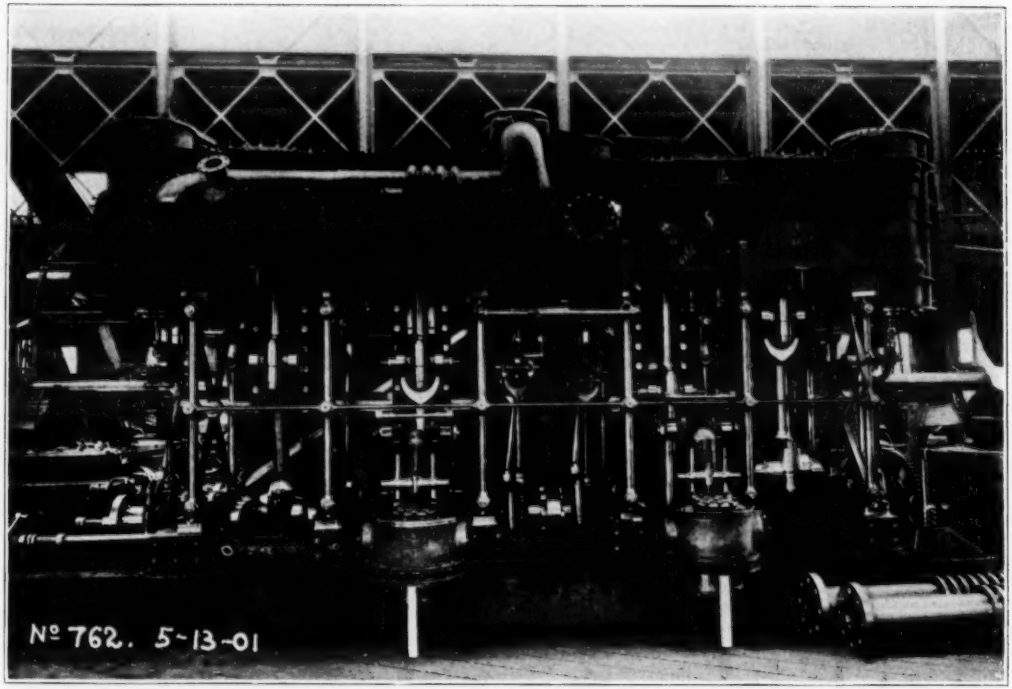
When it is reported on the repair ship that repair work is to be done on board other ships, an engineer officer, if there be one available for that purpose, should immediately go on board the ship requiring repairs, accompanied by the outside foreman. If there is no engineer officer for this duty, the outside foreman should inspect the work alone. For this purpose there should always be a steam launch at the disposal of the engineer officer in charge of the shops. As soon as the inspection is completed and the report made to the officer in charge of the shops, the force composed of the different workmen required and leading men should be immediately dispatched to start the work. This entire job should be given a job order at once. As portions of the work are brought on board the repair ship, each portion should be delivered in a definite part of the ship reserved for receiving work, the record taken, work tagged, and the inside foreman should then assign the different portions of the work to the various shops. In the case of castings where patterns have to be made, the leading patternmaker should be consulted, and, if necessary, dimensioned sketches to scale should be made for him to work with. There should be no attempt made at elaborate drawings, as the free-hand sketches to scale on section paper would answer the requirements. The leadingman in the foundry should be notified at once of the foundry work required, so that he could prepare his heats and metals in advance of receipt of the patterns. It would be frequently necessary to consult the various foremen so that all should work in unison. As work is

finished and brought to the delivery portion of the ship and the record taken, it should be sent to the proper ships at once.

As most of the repair work, however, would be decided upon by the chief engineers of the ships, no inspection would be required, but a force would be sent on board at once, trusting to the reports of the chief engineers. In fact, every detail of the work should be arranged with the idea of saving time. When a large quantity of work should be at hand so that the repair ship would be taxed beyond its limit, the question as to which work is the most important would have to be decided by some one in authority, the matter being even submitted to the senior officer present.

Complete sets of books and a daily log book of repairs should be kept by the clerical force under the engineer officer in charge, and they should also keep and tabulate the experimental data turned in for the different experiments carried on.

Having been on duty for two months connected with fitting up a collier for a repair ship, and having, in conjunction with Naval Constructor R. Stocker, redesigned the colliers *Marcellus*, *Caeser* and *Abarenda* for that purpose, it seems well for me to write up some of the ideas evolved for the benefit of those who may later have this problem presented to them. There was little on record to start with, but many valuable ideas were found in official and private letters from Mr. Gardiner C. Sims, Mr. W. S. Aldrich and Lieutenant Commander John L. Gow, U. S. Navy, who were principally responsible for making the *Vulcan* a success. An article called "Work on the Repair Ship," by Sims and Aldrich, was full of meat. It is hoped that this article may present other ideas, which, added to those which have been filed in the Bureau, will assist in making a success of the repair ship when authorized.



TYPE ENGINE OF DESTROYERS "TRUXTUN," "WHIPPLE" AND "WORDEN."

DESCRIPTION AND TRIALS OF U. S. DESTROYERS *TRUXTUN, WHIPPLE* AND *WORDEN.*

By Rear Admiral John D. Ford, U. S. Navy, Member.

The *Truxtun, Whipple* and *Worden* are twin-screw torpedo-boat destroyers of 433 tons displacement, and were built by the Maryland Steel Company, Sparrows Point, Maryland, in conformity with a circular issued to builders, specifying the characteristics of sixteen torpedo-boat destroyers and twelve torpedo boats. This circular may be found on pages 817 to 825, Volume X, No. 3, of the Journal.

These three vessels were built from the Navy Department's plans and specifications, the contractors submitting all drawings for the approval of the Bureaus concerned before work was commenced. The contract was signed October 4, 1898, the price being $286,000 for each vessel, and the time allowed for completion being eighteen months. The price stated above does not include the ordnance, ordnance outfit, and certain articles, as anchors and chains, which are supplied by the Government. The speed guarantee was thirty nautical miles per hour, to be maintained successfully for two consecutive hours, to be run over a measured course. No premium for speed in excess of that required by the contract was provided for, but if the speed should not fall below twenty-eight knots per hour, the vessel should be conditionally accepted, subject to deductions from the contract price of the vessels at the ratio of $32,000 per knot on account of their failure to reach the speed of thirty knots, and if the vessels make an average speed of less than twenty-eight knots per hour, they shall be rejected. Each vessel is to carry the following weights in addition to that of the completed hull and machinery, with spare parts and the necessary water for trial, viz: torpedo gear and torpedoes, rapid-fire guns and ammunition, fifteen tons; coal, twenty-five tons; crew, boats,

anchors, electric plant, equipment, etc., twelve tons; total, fifty-two tons.

These vessels were successfully launched on the 15th day of August, 1901.

On January 17, 1902, representatives of the contractors addressed a letter to the Navy Department, in which they requested a modification of the requirements of the contracts for building said vessels and for reimbursements for extraordinary expenses incurred by them in the fulfillment of said contracts. The Department approved the recommendation of the Bureaus, that each of said vessels be accepted as soon as it has passed a satisfactory trial as follows: "Standardization runs to be made up to the highest attainable speed of the vessel, these not to be considered satisfactory unless a speed of twenty-eight knots is reached for all destroyers and twenty-six knots for torpedo boats. The Trial Board to be satisfied in each case that the vessels are properly run up to the highest speed attainable with due regard to efficiency and utility. After the standardization trials the destroyers to make a satisfactory run of one hour at an average speed of at least twenty-six knots, and torpedo boats a satisfactory run of one hour at an average speed of at least twenty-four knots. The above requirements to apply to speed alone, and not to operate to change or modify the many other requirements of the vessels for acceptance. In case any vessel fails to make the speed herein required, the case will be dealt with on its merits." The weights of the machinery of the destroyers was limited to 198 tons, which weight included main engines, boilers and the auxiliaries. The penalty for overweight was $200 per ton up to 5 per cent., beyond which a further deduction of $1,000 was to be made.

HULLS.

The hulls are constructed of mild steel of domestic manufacture, with frames spaced 21 inches apart, except in the engine compartments, where intermediate frames are spaced to suit the variations of the engine bed plates.

The thickness of the keel plate is 12½ pounds per square foot

for two-thirds the length amidships; forward and abaft this length it is reduced to 10 pounds per square foot. The vertical keel is 10½ pounds per square foot, with double angles at the top and bottom edges, 3 by 2½ inches by 4 pounds per square foot. The outer plating is 10 pounds per square foot for two-thirds the length amidships, reduced to 8 pounds per square foot at the ends; the garboard strakes are 10 pounds amidships, reduced to 8 pounds at the ends. The seams are lapped and double riveted for two-thirds of their length amidships, single riveted at the ends.

The vessels are each divided into fifteen watertight compartments: first compartment, the trimming tank and stores; second compartment, windlasses and engines; third compartment, crew's quarters; fourth compartment, crew's quarters and men's mess room; fifth compartment, galley and cold storage; sixth compartment, forward boiler room; seventh and eight compartments, engine spaces; ninth compartment, after boiler room; tenth and eleventh compartments, petty officers' quarters and messes; twelfth, thirteenth and fourteenth compartments, officers' quarters and mess rooms; fifteenth compartment, stores.

Main Decks.—On the main decks are located the conning towers, batteries, bridges and boats.

Berth Decks.—On these decks are placed the quarters for the officers and the berthing space for the crew.

The Holds.—In these spaces are located the machinery compartments, fire rooms, magazines, coal bunkers, dynamos, storerooms and chain lockers.

Drainage System.—There are main drain pipes extending fore and aft, and having branches to the bilges in each compartment; all bilge branches are provided with suitable valves.

Armament.—The armament consists of two 12-pounder rapid-fire guns, six 6-pounder rapid-fire guns, two torpedo tubes, and small arms for each vessel.

Coal Bunkers.—There are four coal bunkers on each side of the vessel, divided into watertight compartments, with a total capacity of 171 tons, at 43 cubic feet per ton. There are two hydraulic ash ejectors, one fitted in each fire room.

HULL DATA.

Length over all, feet	264½
between perpendiculars, feet	248
on L.W.L., feet and inches	258–6
Ratio of length to beam	11.24 + 1
Beams to top of floor, amidships, feet and inches	13–4
Mean draught, sea-going trim, feet and inches	9–5
Displacement, sea-going trim, tons	678
per inch at L.W.L., tons	10⅝
Area of immersed midship section, square feet	139
Center of gravity of L.W.L., plane aft of midship section, feet and inches	15–4½
Center of buoyancy above bottom of keel, feet	5
aft of midship section, feet and inches	5–7½
Transverse metacenter above center of buoyancy, feet and inches	6–2½
Longitudinal metacenter above center of buoyancy, feet	720
Number of frames	153

MAIN ENGINES.

There are two vertical, inverted-cylinder, direct-acting triple-expansion engines, placed in separate watertight compartments. In the cylinder arrangement: For the starboard engine, second low-pressure, intermediate, high and first low-pressure; for the port engine, first low-pressure, high, intermediate and second low-pressure. The weights of the pistons are such as to make the weights of the reciprocating parts the same for all cylinders, the weights of the air-pump pistons and moving parts actuating them being taken into consideration.

The main valves are actuated by means of Stephenson double-bar links.

All the main valves are piston valves double-ported for steam, there being one for each high-pressure, two for each intermediate and two for each low-pressure cylinder.

The framing of the engines consists of vertical forged-steel columns, stayed by diagonal braces, and the engine bed-plates consist of a separate steel casting for each bearing, all supported upon and bolted to two fore-and-aft channels, which latter are supported by and form part of the engine keelsons, strongly worked into the framing of the vessels. The crank shafts are made in two sections and are hollow.

The reversing gear consists of a steam cylinder with piston acting directly on an arm fixed on the reversing shaft. The valve of this engine is worked by a system of differential levers, the primary motion being derived from a lever at the working platform, and the secondary motion from a point on the reversing arm. The turning gear consists of a worm wheel on the main shaft worked by a hand ratchet.

ENGINE DATA.

Cylinders, number for each engine	4
H.P., diameter, inches	23
I.P., diameter, inches	34
L.P. (2), diameter, inches	37
Stroke of pistons, inches	22
Valves, one H.P. for each cylinder, upper, diameter, inches	13½
lower, diameter, inches	12⅞
two I.P. for each cylinder, upper, diameter, inches	13½
lower, diameter, inches	12⅞
two L.P. for each cylinder, upper, diameter, inches	13½
lower, diameter, inches	12⅞
Valve stems, H.P. (1), diameter, inches	1¾
I.P. (2), diameter, inches	1¾
L.P. (4), diameter, inches	1¾
Main steam pipe, diameter, inches	9
exhaust pipe to condenser (2), diameter, inches	16
Piston rods, diameter, outside, inches	4½
inside, inches	2½
Connecting rods, center to center, inches	46
diameter, outside, inches	4½ and 5
bore, inches	2½

SHAFTING AND BEARINGS.

The crank, thrust, stern-tube and propeller shafting is hollow and of forged nickel-steel. The crank shaft of each engine is in two lengths, bolted together, with eccentrics forged on. The cranks are set at 90 degrees, the high and first low-pressure and the intermediate and second low-pressure cranks being opposite, the second pair being at right angles with the first pair. The forward end of the stern-tube shaft is supported by a spring bearing. The propeller shafts are covered with a composition

casing from the forward coupling to 1¼ inches inside the propeller hub.

Each thrust bearing is of the collar type, made of cast-steel, which is water-jacketed, and is secured to the after girder of the engine bedplate by a steel strut. The bearing faces are of white metal, and there is an oil cup common to all collars, the white metal being channeled for the distribution of oil.

Crank shaft, diameter, inches	8⅝
axial hole, diameter, forward section, inches	5
aft section, inches	4½
coupling disc, diameter, inches	15⅝
thickness, inches	2
tapered coupling bolts (8), inches	1 1/16
journals, diameter, inches	
length (4), inches	12
length (2), inches	16
length of port shaft, forward section, feet and inches	9– ⅛
aft section, feet and inches	10– 2⅝
starboard shaft, for'd section, feet and inches	9– ⅛
aft section, feet and inches	10– 2⅝
crank pins, diameter, inches	8⅝
length, H.P., inches	14
I.P., inches	14
L.P., inches	14
Thrust shaft, diameter, inches	6½
coupling disc, diameter, inches	15⅝
axial hole, diameter, inches	5⅜
collars, number, each shaft	12
diameter, inches	12
thickness, inch	1
space between, inches	1⅛
length port, feet and inches	6– 3⅜
starboard, feet and inches	6– 3⅜
Stern-tube shaft, diameter, inches	8½
axial hole, diameter, inches	5½
length, feet and inches	18– 4½
Propeller shaft, diameter, inches	8½
axial hole, diameter	5½
length, feet and inches	40–10 5/16
Stern-bracket bearing (2), length, forward, inches	25
aft, inches	34
diameter, inches	9½
Stern-tube bearing, length, forward, inches	30
aft, inches	24

Condensers.—There are two main condensers, one for each engine. The shells are of Muntz metal plate, No. 10 B.W.G., made of cylindrical plates, butted together, secured and stiffened by brass rings of T section. The water heads are of copper, with tube sheets of rolled Muntz metal. The circulating water passes through the tubes, and a baffle plate is is fitted in each condenser to direct the steam over the tubes.

Diameter of shell, inside, inches	44
Thickness of shell	No. 10 B.W.G.
Tubes, diameter, inch	$\frac{5}{8}$
length between tube sheets, inches	156
thickness No. 20 B.W.G., inch	$\frac{1}{8}$
number in each condenser	1,642
Cooling surface, each condenser, square feet	3,496
total, square feet	6,992
Ratio total cooling to total heating surface	1 : 2.541

Air Pumps.—There are twe double-acting, vertical cylinder air pumps of the Bailey type for each engine, worked from the high and intermediate crossheads. The cylinders and casings are made in one casting. The suction nozzle opens into a suction chamber formed around the cylinder of each pump. In the center of each cylinder there is a port extending entirely around the cylinder, connecting it directly with the suction chamber.

Diameter of pump, inches	12½
Stroke of pump, inches	6
Diameter of pump rod, inches	2
Diameter of rock shaft, inches	2½

Circulating Pumps.—There is a single-inlet, water-balanced, centrifugal circulating pump for each condenser. They each have a 7-inch suction branched from the main sea-injection pipe and deliver into the chest of their condenser. There is a gate valve, worked by a hand wheel in the injection pipe, which leaves the pipe unobstructed when the vessel is going at sufficient speed to insure the necessary amount of circulating water being furnished by the action of a scoop, and which diverts the water through the pump at low speed or when the vessel is stopped.

Steam cylinder, diameter, inches	3
Stroke, inches	4
Pump runner, diameter, inches	20
Width at periphery, inches	1¾
Inlet nozzle, diameter, inches	2
Outlet nozzle, diameter, inches	2½

Screw Propellers.—The propellers are of manganese-bronze, tinned and polished, each with three blades. They are true screws, the port one right-handed and the starboard one left-handed. Each propeller is secured to its shaft by a single key and a composition nut which is screwed on and locked in place.

Number of blades	3
Diameter, feet	8
Length of hub, inches	20
Mean pitch as set, feet and inches	11– 3
Greatest width of blade, inches	31 5/16
Helicoidal area each screw, square feet	22.7
Projected area, square feet	17.14
Disc area, square feet	50.26
Pitch ÷ diameter, feet	1.406
Helicoidal area ÷ disc area, square feet	.451
Projected area ÷ disc area, square feet	.341
Weight of one propeller, finished, pounds	2,327

Boilers.—There are four Thornycroft water-tube boilers of the *Speedy* type. In this type of boiler there is one steam drum, situated at the apex of a triangle, and three water drums, one directly under the steam drum and one at each of the lower angles. The steam drum is connected to each of the water drums by a number of curved tubes for the generation of steam. The steam drum is also connected to the water drums by the large down-take pipes situated at the end of the boiler. The grate bars are of steel and are riveted together in groups. The back and front of the furnace is built up to the arch of the tubes with fire bricks, and on each side to the joint of the tubes with the water drum; each boiler is bolted to angle irons, which are riveted to its saddles. The boiler is covered with a casing consisting of ½-inch sheet asbestos (85 per cent. carbonate magnesia, 15 per cent. asbestos fiber) and outside of that a coating of non-conducting material, the whole being protected by light galvan-

ized-steel plate of such size and arrangement that it can be readily removed while the boiler is in place. There are two furnaces to each boiler, the shapes of which are fixed by the arch of the tubes. The circulation of the water is up the small curved tubes to the steam drum and then down the large pipes to the water drums. Each boiler is fitted with main and auxiliary feed-check and stop valves, with internal pipes and feed regulators, bottom blows and surface blows with scum pans, safety valves, steam gauges, glass and mica water gauges, gauge cocks, air cocks and fire extinguishers. The boilers are placed fore and aft, face to face, in two watertight compartments. There are two boilers in a single compartment forward of the engines and two boilers in a compartment abaft the engines. There are four smoke pipes, one for each boiler.

BOILER DATA.

Steam pressure, designed, pounds	240
Number of boilers	4
Length of steam drum, feet and inches	12– 2½
Diameter of steam drum, outside, inches	38⅞
Width over casing, feet and inches	15– 7½
Height, feet and inches	10– 6
Steam drum, diameter, inside, inches	37
thickness, inch	1⅛
Water drums, wing, diameter, inside, inches	7½
center, diameter, inside, inches	18¼
thickness, inch	½
Furnaces, width of grate, feet and inches	11– 3
length of grate, feet	7– 0
Number of furnaces	2
Tubes, diameter, (1,344 tubes), inches	1½
(372 tubes), inches	1¼
(14 tubes), inches	4
number	1,730
thickness, (1,716 tubes)	No. 11 B.W.G.
(14 tubes), inch	⅜
Heating-surface tubes, one boiler, No. 1, square feet	4,403
boilers Nos. 2, 3 and 4, square feet, each	4,455
Grate surface, one boiler, No. 1, square feet	73½
boilers Nos. 2, 3 and 4, square feet	80½
Ratio H.S. to G.S.	56.4 : 1
Smoke pipes (4), diameter oval, inches	45 × 40

Smoke pipes (4), area, each, square feet	10.115
four, square feet	40.46
Height above lower grate, No. 1, feet and inches	26- 3
No. 2, feet and inches	26- 7
No. 3, feet and inches	25-10
No. 4, feet and inches	25- 3
Safety valves for each boiler, one twin, diameter, inches	3½
Main stop valve, diameter, inches	6½
Total heating surface for four boilers, square feet	17,768
grate surface for four boilers, square feet	315

Forced Draft.—The closed fire-room system of forced draft is used. The air is supplied by blowers of the Sturtevant type, the fans being driven by simple enclosed horizontal engines.

Cylinders, steam, diameter, inches	5
Stroke, inches	4
Fan, diameter, inches	57
number of vanes	8
width at rim, inches	14
area of induction nozzle, square inches	706½
area of eduction nozzle, square inches	706½
revolutions to maintain air pressure of 5 inches	900

Feed Pumps.—There is one main feed pump in each engine and fire room and one auxiliary feed pump in each fire room. Each of these pumps has a 10-inch diameter steam cylinder, a 6-inch diameter water cylinder and a stroke of 12 inches. They are of the vertical single-cylinder type. The main feed pumps in the engine rooms draw from the feed tanks, the reserve feed-water tanks, and the air-pump channel ways, and deliver into the main feed pipe, the auxiliary feed pipe, and into the feed tanks, there being a branch with valve from feed main to each tank. The main feed pumps in fire rooms draw from the feed tanks and reserve feed-water tanks and deliver into the main feed pipe. Each auxiliary feed pump is arranged to draw from the feed tanks and reserve feed-water tanks, the boilers in its own compartment and the sea, and discharge into the auxiliary feed pipe, the fire main, the ash ejectors and overboard through the bottom blow.

Fire and Bilge Pumps.—In each engine room near the fire-room bulkhead there is a vertical single-cylinder pump with a steam

cylinder of 6 inches diameter, a water cylinder of 8 inches diameter and a stroke of 12 inches, which draw their water from the sea and from the bilge, through the auxiliary drain pipe, and discharge into the fire main, overboard, and into pipes for putting out fires in boilers.

Engine-Room Water Service.—In each engine room there is a pipe connected with the inlet water chest of the condenser and with a special delivery from the distiller circulating pump, with branches leading to the various parts of the engine.

Feed Tanks.—There is a feed tank of 210 gallons capacity in each engine room, from which the water flows by gravity to the pumps. A part of each tank is fitted as a filter, so managed that the water discharged by the air pumps, will, after descending through the filtering material, flow over a partition at a height sufficient to keep the filtering material always immersed. In addition to the above-mentioned feed tanks there is a feed tank of 2,000 gallons capacity situated in the tenth compartment and connected with all other tanks by a common system of suction pipes.

Steam Traps.—The separators, jackets, main and auxiliary steam pipes, steam heating system and all places where condensed steam can accumulate, are fitted with drain pipes and cocks, or valves, and with Geipel automatic traps, which discharge into the feed tanks.

Steam Ejectors.—There is a steam ejector connected directly with the bilge, in each large compartment. These ejectors lead through the vessel's side above the water line, and are provided with a straightway valve to prevent water returning into the bilge when the vessel rolls. They are connected with the auxiliary steam pipe, and each ejector has a capacity of 2,000 gallons per hour.

Distilling Apparatus and Evaporators.—There are two evaporators and one distiller of the Baird-Davidson type with a combined capacity of 3,800 gallons of potable water in 24 hours at a temperature of 90 degrees Fahrenheit.

Steering Engine.—On the floor of the forward conning tower is a combined hand and steam-steering engine, made by the

Hyde Windlass Co., Bath, Me. The engine has cylinders 4 inches diameter and 4 inches stroke. It is of a vertical type, with the wheel standard aft of it, the shaft of which connects to a worm gear with the engine. A wire rope ¾-inch diameter, connects the quadrant on rudder with the steering engine in the forward conning tower and also with the hand-steering gear in the after conning tower.

Steam Windlass and Capstan.—Has two drums each sufficiently large to hold 75 fathoms of wire cable 2¾ inches in circumference, arranged so that they can be separately driven, clutches being so arranged that they can be readily engaged and disengaged, and each run has an independent brake. The capstan is situated on the forecastle deck, and can be driven by steam or hand by means of a vertical spindle, capable of motion in either direction, either independent of or in conjunction with the windlass.

Air Compressors.—There is one air compressor for the torpedoes installed in the port engine room of each vessel. It is of the Rand type V.

Mechanical Indicators.—There is a mechanical revolution counter in each engine room.

Voice Tubes.—For communication between the conning tower, torpedo-tube stations and engine and fire rooms, there are voice tubes with electric call bells.

Electric Plant.—The installation consists in general of one 5-kilowatt generating set, one hundred incandescent lights, one searchlight, one set of signaling apparatus, one main switchboard, together with the necessary wiring, accessories, conduits and fixtures. Annunciators, press buttons and bells are provided in connection with the speaking tubes for communication between the conning towers and the various compartments of the vessel.

MACHINERY WEIGHTS (IN TONS OF 2,240 POUNDS).

	Dry.	Wet.
Engine-room and stern weights	92.68	97.77
Forward fire-room weights, including bow	45.82	50.45
After fire-room weights	50.28	54.90

Summary.

Engine-room and stern weights	92.68	97.77
Fire-room weights	96.10	105.35
Total	188.78	203.12
Tools, stores, etc.		.87
Distilling and heating plants		2.68
Total weight		206.67

Detail Weights for One Engine.

Cylinder and fittings	9.88
Shafting	10.20
Reciprocating parts	2.81
Framing, bed plates and bearings	7.0
Valves and valve gear	2.0
Condensers	3.82
Air and circulating pumps	1.15
Boiler, fittings and uptakes (one boiler)	18.82
Smoke pipe (one)	.81

For One Vessel.

Steam, exhaust, suction, discharge pipes and valves	17.87
Lagging and clothing	2.62
Floor plates	3.63
Auxiliaries	8.14
Fittings and gear	3.68

THE TRIALS.

The official trials of the *Truxtun*, *Whipple* and *Worden* were held on the Barren Island course, Chesapeake Bay, Md., the *Truxtun* on June 25, 1902, and June 26, 1902; the *Whipple* on July 17, 1902, and July 18, 1902; and the *Worden* on September 11, 1902, and September 12, 1902. Each vessel was required to undergo two trials: the first a standardization propeller trial, and the second a one-hour run at full speed, at the average number of revolutions necessary for a speed of 28 knots, as determined by the standardization of the propeller on the previous trial.

The several double runs were made as nearly as practicable at the rates of speed prescribed by the precept for the trial. At a

signal given by the observer, who marked with a stop-watch the time of passing the range marks placed at the ends of the measured-mile course, the two counters were thrown into gear at the moment of entering, and out of gear at the moment of leaving the course. Readings of the engine-room gauges were taken and recorded during each run. Table "A" gives the data observed in the engine rooms and at the counters on deck for each run of the *Truxtun* over the measured mile. The points obtained from the observed revolutions of the engines and the corresponding speeds of the vessel on the measured mile were used to determine the revolutions necessary for a speed of 28 knots.

The trials were conducted by the U. S. Naval Board of Inspection and Survey.

DATA OF STANDARDIZATION TRIAL OF THE "TRUXTUN."

Draught at beginning of trial, forward, feet and inches	6– 4
aft, feet and inches	9– 9
mean, feet and inches	8– 0½
ending of trial, forward, feet and inches	6– 2
aft, feet and inches	9– 7¾
mean, feet and inches	7–10⅜
Displacement at beginning of trial, tons	498.3
ending of trial, tons	479

The above was read from mean of salt and fresh-water curves and draughts taken at Annapolis before starting and after returning, respectively.

On June 26th, 1902, the *Truxtun* started to run the full one-hour contract-speed trial.

The trial lasted exactly one hour. The counter readings were recorded every five minutes, and the engine-room gauges were read every ten minutes. The observed data are given in the following Table "B." The coal used during the full-power speed trial was hand-picked Pocahontas of excellent quality, supplied to the fire room in bags weighed by the contractors' force. The quantity of coal consumed per hour was 31,000 pounds.

TABLE A.

STANDARDIZATION TRIAL OF U. S. TORPEDO-BOAT DESTROYER *TRUXTUN* ON BARREN ISLAND COURSE, CHESAPEAKE BAY, MD., JUNE 25, 1902.

.....	First double run.		Second double run.		Third double run.		Fourth double run.		Fifth double run.	
Direction of run	S.	N.	S.	N.	S.	N.	S.	N.	S.	N.
Duration of run, minutes and seconds	2 28·4	2 35·2	2 18·3	2 17·8	2 09·7	2 10·0	2 03·8	2 05·1	2 02·6	2 00·8
Speed, knots	24.259	23.196	26.030	26.125	27.756	27.692	29.079	28.777	29.364	29.801
Mean speed during double run, knots	23.7275		26.0775		27.724		28.928		29.5825	
Total revolutions port engine	628	662	637	661	643	660	653	661	653	666
starboard engine	639	671	648.5	673	657	672.5	666.5	673	673	674
Mean revolutions for double run	256.9		284.65		304		319.85		328.65	
apparent slip of propellers	16.82		17.48		17.85		18.54		18.93	
Steam pressure above atmosphere in engine room, main steam pipe.....port	116	119	145	157	180	181	200	200	225	235
Ditto.....starboard	118	119	145	156	177	180	200	198	222	232
H.P. valve chest.....port	...	...	...	...	...	...	...	...	...	...
Ditto.....starboard	...	...	...	...	...	...	...	...	...	...
Steam pressure above atmosphere, first receiver.....port	45	47	58	62	74	75	81	78	75	78
Ditto.....starboard	40	41	53	57	64	67	74	73	76	77
Steam pressure above atmosphere, second receiver.....port	1	.9	5.2	8	13.5	14.2	15.4	14.9	13	17
Ditto.....starboard	2.5	2	7	10	13.2	14.2	15.3	15	16.3	16.4
Vacuum.....port	25.8	25.7	26	26	25.6	25.7	25.1	25	25.2	25
Ditto.....starboard	26.8	26	25.8	25.8	25 4	25.4	25	25	25	25
Air pressure forward fire room	.8	2	2.5	2.4	5.1	5.2	6.2	5.7	6.4	6.3
after fire room	1	.7	2	3.8	3.6	3	4.8	5.3	5.9	6
Injection	68	68	68	68	68	68	68	68	68	68
Discharge.....port	120	118	117	117	117	116	118	119	119	119
starboard	114	114	114	115	116	116	116	115	117	116
Feed water.....port	215	210	220	218	224	244	200	190	190	190
starboard	210	205	215	220	220	240	200	190	190	200

NOTE.—The points obtained from the observed revolutions of the engines and the corresponding speeds of the vessel on the measured mile being plotted gave very satisfactory curves, and the mean engine speed required for a speed of 26 knots of the vessel deduced from these curves was found to be 283.8 revolutions per minute.

TABLE B.

FULL-POWER CONTRACT-SPEED TRIAL, U. S. TORPEDO-BOAT DESTROYER *TRUXTUN.* BARREN ISLAND COURSE, CHESAPEAKE BAY, MD., JUNE 26, 1902.

	A. M.	A. M.	A. M.	A. M.	A. M.	A. M.	A. M.	Mean.
Time	9·48	9·58	10·08	10·18	10·28	10·38	10.48	...
Stbd. engine counter	00,000	3,021	6,063	9,101	12,159	15,265	18,381	...
Revolutions per minute	...	302.1	304.2	303.8	305.8	310.6	311.6	306.35
Steam pipe, engine room	180	187	187	180	185	180	187	183.7
H.P. valve chest	...	...	...	...	...	...	...	...
First receiver	65	68	68	64	67	66	69	66.9
Second receiver	12	13.5	13	12	13	12.5	13	12.7
Vacuum, inches	25	25	25	25.2	25	25	25	25
Injection	66	66	66	66	66	66	66	66
Delivery	116	115.5	115.5	114.5	115	115.5	116	115.4
Feed	172	168	150	180	160	160	160	162.9
Air pressure, fire room	4.4	4	3.8	4.6	4.6	4.7	5	4.6

TABLE C.

FULL-POWER CONTRACT SPEED TRIAL, U. S. TORPEDO-BOAT DESTROYER *TRUXTUN.* BARREN ISLAND COURSE, CHESAPEAKE BAY, MD, JUNE 26, 1902.

	A. M.	A. M.	A. M.	A. M.	A. M.	A. M.	A. M.	Mean.
Time	9.48	9·58	10·08	10·18	10·28	10·38	10·48	...
Port-engine counter	00,000	2,985	5,980	9,030	12,030	15,080	18,140	...
Revolutions per minute	...	298.5	295.5	305	300	305	306	302.33
Steam pipe, engine room	177	186	184	177	180	180	185	181.3
H.P. valve chest	...	...	...	...	...	...	...	...
First receiver	73	75	74	72	74	72	76	73·7
Second receiver	10	10.2	10.3	11	11.3	11	12	10.8
Vacuum, inches	25.2	24.9	25	25.2	25.2	25.1	25.1	25.1
Injector	70	70	70	69	69	69	69	69.4
Discharge	132	132	132	132	132	133	133	132.3
Feed	190	175	160	140	148	140	160	159
Air pressure, fire room	4.2	4	3·7	4.3	4.8	4.4	4.4	4.26

Average revolutions per minute for one hour, both engines, 304.35. Corresponding speed of vessel, knots, 27.67.

DATA ONE-HOUR TRIAL RUN, "TRUXTUN."

Hull weights to date, pounds	511,840
Steam-engineering weights, including water in pipes, condensers and boilers, pounds	459,028
Ordnance weights, including air-compressing plant and piping, pounds	8,015
Articles comprising equipment within the meaning of the contract, pounds	8,288
Reserve feed water, pounds	17,472
Total, pounds	1,004,692

Put on board for trial :	
Coal, pounds	59,136
Men, pounds	11,424
Provisions, temporary outfit, oils, etc., pounds	26,656
Total in tons	41.9
Draught at beginning of trial, forward, feet and inches	6- 1
aft, feet and inches	9- 8¼
mean, feet and inches	8- 0⅛
Displacement, tons	494.6
Draught at end of trial, forward, feet and inches	6- 1
aft, feet and inches	9- 7½
mean, feet and inches	7-10⅛
Displacement, tons	477.2
mean for trial, tons	486

The official report of the speed for one hour was 27.67 knots, at an engine speed of 304.35 revolutions per minute.

The data on Tables "D" show the comparative speed, revolutions and steam pressures for the three vessels.

The time of completion of the *Truxtun* was extended to August 16, 1902, when the vessel was preliminarily accepted by the Government.

DATA OF STANDARDIZATION TRIAL OF THE "WHIPPLE."

Draught at beginning of trial, forward, feet and inches	6- 4
aft, feet and inches	9- 8¼
mean, feet and inches	9- 0⅛
ending of trial, forward, feet and inches	6- 0
aft, feet and inches	9- 8
mean, feet and inches	7-10
Displacement at beginning of trial, tons	497.4
ending of trial, tons	477.44

On July 18th, 1902, the *Whipple* started to run the full one-hour contract speed trial.

The trial lasted exactly one hour. The counter readings were recorded every five minutes, and the engine-room gauges were read every ten minutes. The observed data are given in the two following tables, "F" and "G."

The quantity of coal, Pocahontas of excellent quality, consumed per hour was 21,900 pounds.

TABLE D.

TRIAL TRIP OF TORPEDO-BOAT DESTROYER *TRUXTUN*, JUNE 14, 1902, OVER BARREN ISLAND COURSE.

Run.	No. 1, south.	No. 2, north.	No. 3, south.	No. 4, north.	No. 5, south.	No. 6, north.	No. 7, south.	No. 8, north.	No. 9, south.	No. 10, north.
Steam, pounds	109.5	111	131	135.5	152.5	164	184.5	173	193.5	195.5
M.P. receiver	F. 35 A. 35	F. 35 A. 35	F. 50 A. 50	F. 50 A. 55	F. 60 A. 65	F. 60 A. 65	F. 75 A. 75	F. 55 A. 65	F. 55 A. 75	F. 55 A. 75
L.P. receiver	F. .5 A. 1	F. 1 A. 1	F. 4 A. 4	F. 4 A. 4	F. 8 A. 9	F. 8 A. 9	F. 15 A. 16	F. 10 A. 10	F. 13 A. 13	F. 15 A. 15
Vacuum	F. 25 A. 26	F. 26 A. 25	F. 26 A. 25	F. 26 A. 25	F. 26 A. 25	F. 25 A. 25	F. 25 A. 26	F. 25 A. 25	F. 25 A. 25	F. 25 A. 25
Total I.H.P.	3,353.16	3,368.61	4,599.27	4,778.73	5,975 40	6,071.93	7,286.75	6,364.37	7,551.21	7,915.84
Speed, knots	21.712	22.277	23.872	24.725	25.862	26.315	27.825	26.745	28.39	28.09
Slip, per cent	16.49	14.50	17.80	16 59	17.80	17.24	18.20	17.53	16.36	18.725

Run.	No. 1, south.		No. 2, north.		No. 3, south.		No. 4, north.		No. 5, south.		No. 6, north.	
	Port.	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*
Air pressure	.75	2.	.5	.75	2	1.5	1.25	1.75	2	2.5	2	2.5
Revolutions per minute	234.2	234.2	235	234.3	261.2	261.8	266.6	267.3	282.9	284.2	285.9	286.8
M.E.P., H.P. cylinder	52.875	50.05	54.75	51	62.50	62.25	64.25	63.375	72.	75.50	74.50	76.50
M.P. cylinder	25.5	24.5	25.05	25	31	30.50	31.50	31	38	36.50	37	37
No. 1, L.P. cylinder	9.875	10	9.125	9.875	12	12.25	11.75	12.375	14	15	14.25	15.145
No. 2, L.P. cylinder	9.50	9.875	9.63	9.875	11.875	12.375	12.25	13.25	14 50	15.125	14	15
I.H.P., H.P. cylinder	560.96	530.99	582.10	542.23	757	737.69	777 11	766 53	724.34	969.27	966.56	992.50
M.P. cylinder	597.21	573.79	587.92	586.75	810.96	788.88	836.05	827.70	1,076.92	1,034.41	1,059.68	1,059.68
No. 1, L.P. cylinder	274.29	277.76	252.81	274.87	372.31	380.06	372.08	391 87	470.56	504.17	484.03	514.43
No. 2, L.P. cylinder	263 87	274.29	268.06	274.87	368.43	383.94	387.91	419.58	487.36	508.37	475.54	519.51
Total I.H.P.	1,696.33	1,656.83	1,689.89	1,678.72	2,308.70	2,290.57	2,373.15	2,405.68	2,959.18	3,016.22	2,985.81	3,086.12

Run.	No. 7, south.		No. 8, north.		No. 9, south.		No. 10, north.		General remarks.
	Port.	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	
Air pressure	4.5	4.5	5.25	5	5.5	4.5	5.5	5	Length over all, 259 feet 6 inches.
Revolutions per minute	305.5	307.5	290.7	293.4	306.4	307.4	311.3	311.3	Beam, 22 feet 6 inches.
M.E.P., H.P. cylinder	85.50	84.625	81.75	85.50	88.50	89.06	86.25	88.50	Draught, mean, 6 feet 8¼ inches.
M.P. cylinder	41.05	39	37.50	37.00	43.50	42.50	49.75	42.50	Displacement, 509.8 tons.
No. 1, L.P. cylinder	16.50	17.145	12.875	14.875	15.07	18.125	16.25	16.125	Engines, 23 inches by 34 inches by 37 inches by 37 inches by 22 inches stroke.
No. 2, L.P. cylinder	17.75	16.625	15	14.25	17	17	19.75	17.75	Boilers, four Thornycroft.
I.H.P., H.P. cylinder	1,187.64	1,174.59	1,077.21	1,131.35	1,229.98	1,237.76	1,216.29	1,248.02	H.S., 17,768 sq. ft. G.S., 315 sq. ft.
M.P. cylinder	125.77	1,194.96	1,095.38	1,080.77	1,334.58	1,303 9	1,548.72	1,323.03	Propellers:
No. 1, L.P. cylinder	599.60	623.03	446.03	515.32	548.34	659.50	599 95	595.34	Diameter, 8 ft. Pitch, 11 ft. 3 in.
No. 2, L.P. cylinder	645.02	604.14	519.65	493.66	618.57	618.57	729.17	655.33	
Total I.H.P.	3,690.03	3,596.72	3,138.27	3,221.10	3,731.47	3,819.73	4,094.13	3,821.72	

Mean revolutions per minute	234.45	264.3	284.9	299.3	309.05
I.H.P.	3,360.89	4,689	6,023.67	6,825.56	7,733.524
speed, knots	21.995	24.298	26.088	27 285	28.24
slip, per cent	15.495	17.195	17.52	17.865	17.54
ref. pressure	29.60	37.75	44 99	48.53	53.25

Built by—
Marine Department,
Maryland Steel Co.,
Sparrow Point,
Md.

Mean revolutions per minute	294.45	294.3	304.9	299.3	309.05	
I.H.P.	3,360.89	4,689	6,023.67	6,825.56	7,733.524	Built by—
speed, knots	21.995	24.298	26.088	27 285	28.24	Marine Department,
slip, per cent	15.495	17.195	17.52	17.865	17.54	Maryland Steel Co.,
ref. pressure	29.60	37.75	44 99	48.53	53.25	Sparrow Point, Md.

TABLE D.

STANDARDIZATION TRIAL OF TORPEDO-BOAT DESTROYER *WHIPPLE*, JULY 17, 1902, OVER THE BARREN ISLAND COURSE.

Run.	No. 1, south.		No. 2, north.		No. 3, south.		No. 4, north.		No. 5, south.		No. 6, north.		No. 7, south.		No. 8, north.	
	Port.	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*
Steam, pounds	112.5	109	114.5	113.5	150.5	150	150	149	178.5	179.5	180.5	180	203.5	201	203.5	206
I.P. receiver	45	...	46	...	62	55.3	62	55	75	69	75	70	83	77	83	78
L.P. receiver	.5	26	.5	2.6	...	5	1	5.1	6	10.2	6	10.5	10	14	10.8	15
Vacuum	26.8	26	26.6	26.3	26.4	26.2	26.4	26.2	25.9	25.9	25.8	26	25.3	25.6	25.3	25.5
Revolutions per minute	244.3	245.8	251.9	253.1	278.3	281.3	281.3	282.9	302.5	304.8	303.8	306.1	314.5	317.3	317.2	318.1
M.E.P. of H.P. cylinder	47.25	52.5	49.5	56	65	67.5	64	65	75	67	71	66	77	71	82	73
M.P. cylinder	25.5	26	27.5	25	36	32	33.5	31.5	41.75	37	40.25	37	40.25	40	44.25	41
1st L.P. cylinder	10	9	10.5	9	13.5	12.25	13.5	12.5	16.5	13.5	16.5	14	17.75	16	17.25	14.5
2d L.P. cylinder	8	9.5	10	8	13	11	12.5	11.5	15	13.5	16	13.5	17	15	15	13
I.H.P. of H.P. cylinder	522.91	584.57	564.85	642.06	819.45	860.15	815.54	833	1,027.74	925.10	977.11	915.18	1,097.01	1,020.53	1,178.27	1,051.92
M.P. cylinder	622.97	639.08	692.73	632.75	1,001.88	900.16	942.36	891.14	1,262.94	1,127.76	1,222.80	1,132.57	1,265.86	1,269.20	1,403.61	1,304.21
1st L.P. cylinder	289.74	262.37	313.69	270.16	445.59	408.69	450.39	419.40	591.96	488.02	594.51	508.25	662.07	602.11	748.94	547.04
2d L.P. cylinder	231.79	276.94	298.75	240.14	429.08	366.98	417.03	385.85	538.15	488.02	576.49	490.10	634.09	564.48	564.30	490.45
Total I.H.P.	1,667.41	1,762.96	1,870.02	1,785.11	2,696	2,535.98	2,625.32	2,529.39	3,420.79	3,028.90	3,370.91	3,046.10	3,659.03	3,456.32	3,895.12	3,393.62
Grand H.P. total	3,430.37		3,655.13		5,231.98		5,154.71		6,449.69		6,417.01		7,115.35		7,288.74	
Speed in knots	22.642		23.841		25.568		26.374		27.46		28.147		27.95		28.526	
Slip, per cent	16.79		14.95		17.67		15.78		18.54		16.85		20.28		19.09	
Air pressure	F. 1.3	A. 2.8	F. 1.35	A. 2.55	F. 2.6	A. 3.1	F. 2.95	A. 3.45	F. 3.25	A. 5.3	F. 3.45	A. 5.45	F. 2.9	A. 5.65	F. 5.4	A. 5.75

TABLE D.

STANDARDIZATION TRIAL OF TORPEDO-BOAT DESTROYER *WORDEN*, AUGUST 23, 1902, OVER BARREN ISLAND COURSE.

	Run.	No. 1, south.		No. 2, north.		No. 3, south.		No. 4, north.		No. 5, south.		No. 6, north.		No. 7, south.		No. 8, north.	
		Star.	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*
From gauge.	Steam, pounds	100	108	109	108	145	148.5	171.5	177.5	174	180	176.5	180	200	200	197.5	201
	I.P. receiver	40	37.5	40	38	40	55	41	65	41	64.1	41	68.5	41	75	41	66.6
	L.P. receiver	—1	—1	1	...	8	5	11	9	11.5	9.5	11.5	10	15	14	13	12.6
	Vacuum	24	27.7	24	27.8	23.5	27.5	23.5	26	23.75	28.2	23.5	25.5	22.5	25	22.5	26
Revolutions per minute		247.6	241.6	247.8	241.6	282.5	275.8	300.4	294.6	303.4	296.6	304.6	299.1	323.8	314.2	321.2	315.5
M.E.P. of 1st L.P. cylinder		10.75	11	11.9	12	14.9	15.1	16.8	16.6	16.5	16.75	17	16.1	18.4	17.25	17.15	16.35
H.P. cylinder		56.25	47.25	52	52.5	66	70	76.25	77.25	76	79.25	78.5	79	83.75	84.75	83.75	84.68
M.P. cylinder		27	26	28.5	27	36	36.5	40.5	39.5	41	42.5	41.5	44	45.75	44.5	45	44.5
2d L.P. cylinder		10.6	11	11.75	12	14.75	16.5	16.8	17.7	16.9	18.25	17.9	17.5	19	18 5	17.7	16
I.H.P. of 1st L.P. cylinder		315.68	315.19	349.73	343.85	499.22	493.92	598.54	580	593.72	589.21	614.13	571.12	706.61	642.81	653.32	611.79
H.P. cylinder		630.92	517.13	583.72	574.59	844.62	874.56	1,037.62	1,030.93	1,044.55	1,064.80	1,082.17	1,070.30	1,228.46	1,206.27	1,291.34	1,210
M.P. cylinder		668.52	628.16	706.23	652.32	1,026	1,006.67	1,351.8	1,163.67	1,243.94	1,260.55	1,264.09	1,316.04	1,481.49	1,398.19	1,445.40	1,403.97
2d L.P. cylinder		311.27	315.19	345.32	343.85	394.19	539.71	598.54	618.43	608.12	641.98	646.65	620.78	731.45	689.39	674.28	598.69
Total I.H.P. one engine		1,926.39	1,775.67	1,985	1,914.61	2,764.03	2,914.86	3,586.5	3,363.03	3,490.33	3,556 54	3,607.04	3,578.33	4,147.91	3,936.66	4,064.34	3,824.45
two engines		3,702.06		3,899.61		5,678.89		6,979.53		7,046.87		7,175.37		8,084.57		7,888.79	
Speed in knots		23.968		22.194		26.905		26.864		28.8		27.231		30.354		28.21	
Slip, per cent		11.78		13.66		13.17		18.4		13.5		18.75		14.28		19.9	
Temperature.	Injection, degrees	76		...		...		...		...		...		...		...	
	Outboard delivery, deg.	100		100		101		111		112		113		115		107	
	Feed suction, degrees	41		41		52.5		75		75		72.5		68.5		62.5	
	Heater discharge, deg.	205		220		210		222		240		240		Not working.		...	
Air pressure		F. 1.25	A. 2	F. 1.25	A. 1.5	F. 4	A. 2.5	F. 3	A. 4.5	F. 3.125	A. 4.5	F. 4.75	A. 5	F. 5.5	A. 5.5	F. 7	A. 6

Temperature	Feed suction, degrees....	41	41	52.5	75	75	72.5	68.5	62.5
	Heater discharge, deg...	205	220	210	222	240	240	Not working.	...
Air pressure.....		F. 1.25 A. 2	F. 1.25 A. 1.5	F. 4 A. 2.5	F. 3 A. 4.5	F. 3.125 A. 4.5	F. 4.75 A. 5	F. 5.5 A. 5.5	F. 7 A. 6

TABLE E.

STANDARDIZATION TRIAL OF U. S. TORPEDO-BOAT DESTROYER *WHIPPLE* ON BARREN ISLAND COURSE, CHESAPEAKE BAY, MD., JULY 17, 1902.

.....	First double run.		Second double run.		Third double run.		Fourth double run.	
Direction of run.....	S.	N.	S.	N.	S.	N.	S.	N.
Duration of run, minutes and seconds.....	2 39·0	2 31·0	2 20·8	2 16·5	2 11·1	2 07·9	2 08.8	2 06·2
Speed, knots.....	22.642	23.84	25.568	26.374	27.460	28.147	27.950	28.526
Mean speed during double run.....	23.2415		25.971		27.8035		28.238	
Total revolutions port engine.....	647.5	634	653	640	661	647.5	675.5	667
starboard engine.....	651.5	637	660	643.5	666	652.5	681	669
Mean revolutions for double run.....	248.8		280.905		304.27		316.715	
apparent slip of screw.....	15.80		16.72		17.65		19.72	
Steam pressure above atmosphere in engine room, main steam pipe.....port.....	113	113	152	150	180	183	206	204
Ditto.....starboard...	110	113	150	149	180	180	201	206
H.P. valve chest.....port.....	...	...	...	...	...	...	...	...
Ditto.....starboard...	...	...	...	...	...	...	...	...
Steam pressure above atmosphere, first receiver, port..	46	42.3	61.6	61.6	72.6	74.3	84.6	83
Ditto.....starboard...	25.8	26	55.3	55.3	69.3	70	77	77.7
Steam pressure above atmosphere, second receiver, port.....	−4.6	−4.6	...	+1	6	6	10.3	10.7
Ditto.....starboard...	+2.6	2.7	5	5.1	10.2	.5	14	14.6
Vacuum.....port.....	26.8	26.6	26.4	26.4	25.9	25.8	25.3	25.3
Ditto.....starboard...	26	26.3	26.2	26.2	25.9	26	25.6	25.5
Air pressure forward fire room.....	2.8	2.5	3.1	3.4	5.3	5.5	6	5.7
after fire room.....	1.3	1.4	2.8	3	3.2	3.4	2.9	5.4
Injection.....	77.5	77.5	77.5	77.5	77.5	77.5	77.5	77.5
Discharge .....port.....	115	115	115	115	122	122	119	118
starboard...	110	117.5	107.7	106	110	109.5	110	110
Feed water.....port.....	180	190	200	200	235	235	235	230
starboard...	197	187	194	204	220	220	220	220

NOTE.—The points obtained from the observed revolutions of the engines and the corresponding speeds of the vessel on the measured mile being plotted gave very satisfactory curves, and the mean engine speed required for a speed of 26 knots of the vessel deduced from these curves was found to be 281.2 revolutions per minute.

TABLE F.

FULL-POWER CONTRACT-SPEED TRIAL, U. S. TORPEDO-BOAT DESTROYER *WHIPPLE*. BARREN ISLAND COURSE, CHESAPEAKE BAY, MD., JUNE 18, 1902.

	A. M.	A. M.	A. M.	A. M.	A. M.	A. M.	A. M.	Mean.
Time	9·15	9·25	9·35	9·45	9·55	10·05	10·15	...
Stbd.-engine counter	00,000	2,878	5,873	8,879	11,903	14,931	18,011	...
Revolutions per minute	...	287.8	299.5	300.6	302.4	302.8	308	300.18
Steam pipe, engine room	162	173	180	177	180	172	190	177.7
H.P. valve chest:								
First receiver	62	65	70	68	70	65	72	67.4
Second receiver	8	9	11	10.5	11	10	13	10.3
Vacuum, inches	26.2	26.2	26	25.8	26	26	26	26
Injection	77.5	77.5	77.5	78	78	78	78	77.8
Discharge	107	108	109	110	109	110	110	109
Feed	205	212	215	220	222	250	240	223
Air pressure, fire room	4.1	3.9	2.5	3.2	2.9	2.9	4.2	3.53

TABLE G.

FULL-POWER CONTRACT-SPEED TRIAL, U. S. TORPEDO-BOAT DESTROYER *WHIPPLE*. BARREN ISLAND COURSE, CHESAPEAKE BAY, MD., JUNE 18, 1902.

	A. M.	A. M.	A. M.	A. M.	A. M.	A. M.	A. M.	Mean.
Time	9·15	9·25	9·35	9·45	9·55	10·05	10·15	...
Port-engine counter	00,000	2,860	5,855	8,880	11,875	14,880	17,940	...
Revolutions per minute	...	286	298.5	303.5	299.5	300.5	306	299
Steam pipe, engine room	164	174	179	182	181	173	190	177.6
H.P. valve chest:								
First receiver	72	73	74	74	74	72	77	77.3
Second receiver	2	4	7	7	7	7	9	6.2
Vacuum, inches	26.4	26.2	25.8	25.8	25.9	25.9	25.7	26
Injection	78	78	78	78	78	78	78	78
Discharge	114	116	118	118	118	117	118	117
Feed	210	200	218	225	230	230	230	215
Air pressure, fire room	4.8	5.1	5.3	5.3	5.4	4.8	5.4	5.16

Average revolutions per minute for one hour, both engines, 299.59. Corresponding speed of vessel, knots, 27.44.

DATA OF ONE-HOUR TRIAL RUN, "WHIPPLE."

Hull weights to date, pounds	506,688
Steam-engineering weights, including water in pipes, condensers and boilers, pounds	461,833
Ordnance weights, including air-compression plant, and piping, pounds	8,512
Articles comprising equipment, within the meaning of the contract, pounds	8,960
Reserve feed water, pounds	28,896

Put on board for trial:	
Coal, pounds	68,992
Men, pounds	12,096
Provisions, temporary outfit, oils, etc., pounds	26,686
Total in tons	501.19
Draught at beginning of trial, forward, feet and inches	6- 5
aft, feet and inches	9- 3⅜
mean	8- 1 5/16
Displacement, at beginning of trial, tons	503.3
Draught at end of trial, forward, feet and inches	6- 3
aft, feet and inches	9- 7½
mean	7-11½
Displacement at end of trial, tons	480.7
mean for trial, tons	492

The official report of the speed for one hour was 27.44 knots, at an engine speed of 299.59 revolutions per minute.

DATA OF STANDARDIZATION TRIAL OF THE "WORDEN."

Draught at beginning of trial, forward, feet and inches	6- 3
aft, feet and inches	9- 8½
mean, feet and inches	7-11¾
ending of trial, forward, feet and inches	5-11½
aft, feet and inches	9- 6¾
mean, feet and inches	7- 9⅛
Displacement at beginning of trial, tons	492.6
ending of trial, tons	467.8
mean for trial, tons	480.2

TABLE H.

FULL-POWER CONTRACT-SPEED TRIAL, U. S. TORPEDO-BOAT DESTROYER *WORDEN.* BARREN ISLAND COURSE, CHESAPEAKE BAY, MD., SEPTEMBER 12, 1902.

	A. M.	A. M.	A. M.	A. M.	A. M.	A. M.	A. M.	Mean.
Time	9·40	9·50	10·00	10·10	10·20	10·30	10·40	...
Port-engine counter	00,000	3,080	6,190	9,298	12,437	15,551	18,681	...
Revolutions per minute	...	308	311	310.8	313.9	311.4	313	311.35
Steam pipe, engine room	190	195	195	200	200	195	205	197.1
H.P. valve chest:								
First receiver	70	75	75	77	77	78	80	76
Second receiver	12	13	14	14	14.5	14	14.5	13.7
Vacuum, inches	25	24.5	24.5	25.25	25.5	25.5	25.5	25.1
Injection	76	76	76	76	76	76	76	76
Discharge	121	123	122	123	122	126	115	121.7
Feed	216	245	242	240	210	230	238	231.6
Air pressure, fire room	5	5	5	5	5.25	5.25	6	5.24

TABLE I.

FULL-POWER CONTRACT-SPEED TRIAL, U. S. TORPEDO-BOAT DESTROYER *WORDEN*. BARREN ISLAND COURSE, CHESAPEAKE BAY, MD., SEPTEMBER 12, 1902.

	A. M.	A. M.	A. M.	A. M.	A. M.	A. M.	A. M.	Mean.
Time	9·40	9·50	10·00	10·10	10·20	10·30	10·40	...
Stbd.-engine counter	00,000	3,087	6,200	9,314	12,450	15,564	18,693	...
Revolutions per minute	...	308.7	311.3	311.4	313.6	311.4	312.9	311.55
Steam pipe, engine room	190	190	195	195	200	200	205	197.9
H.P. valve chest:								
First receiver	72	70	72	72	74	74	75	72.7
Second receiver	11	13	13	12	13	13	14	12.7
Vacuum, inches	26	25.5	25.5	25.5	25.5	25.5	25.5	25.6
Injection	76	76	76	76	76	76	76	76
Discharge	107	110	111	111	112	113	114	111.1
Feed	216	218	218	216	215	216	216	216
Air pressure, fire room	4.5	5.2	5	5.3	5.3	5	3.5	4.9

Average revolutions per minute for one hour, both engines, 311.45. Corresponding speed of vessel, knots, 28.15.

On September 12, 1902, the *Worden* started to run the full one-hour contract trial.

The trial lasted exactly one hour. The data were obtained as in the former trials and are given in the preceding two tables, "H" and "I."

The coal used was of the same name and quality as that used on the trials of the other two vessels. The quantity of coal consumed per hour was 28,500 pounds.

DATA OF ONE-HOUR TRIAL RUN, "WORDEN."

Hull weights to date, pounds	502,432
Steam-engineering weights, including water in pipes, condensers and boilers, pounds	463,006
Ordnance weights, including air-compressing plant and piping, pounds	8,288
Articles comprising equipment within the meaning of the contract, pounds	10,976
Reserve feed water, pounds	25,760
Total, pounds	1,010,462
Put on board for trial:	
Coal, pounds	59,584
Men, pounds	10,976
Provisions, temporary outfit, oils, etc., pounds	21,728
Total in tons	492.3

OVER

Mean.
...
...
311.55
397.9

72.7
12.7
25.6
76
311.1
216
4.9

Cor-

full

ed as
bles,

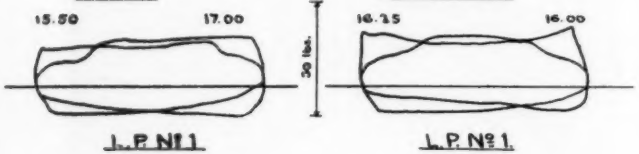
used
coal

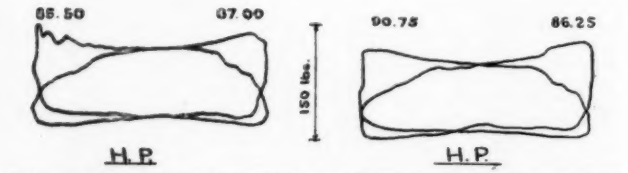
.432
,006
,288
,976
,760
,462
,584
,976
,728
492.3

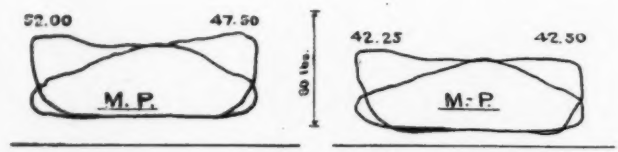
Truxtun.

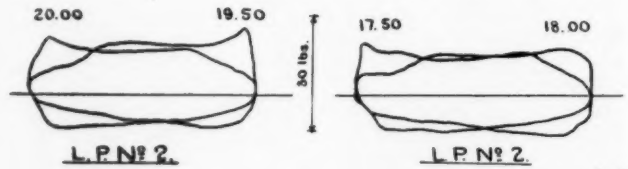
Cards Nº 10.

Port. Starboard.





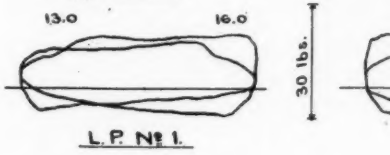


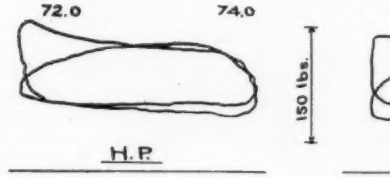


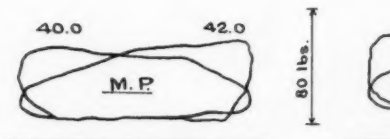
Whipple.

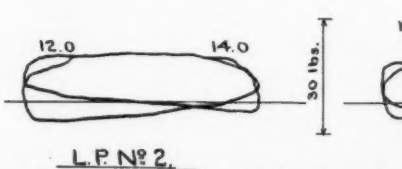
Cards Nº

Starboard.









Maximum Cards of Torpedo Boats

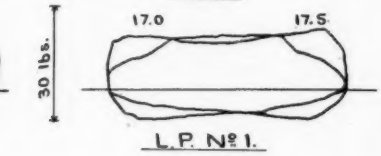
	Port.	Stbd.
Revolutions	311.3	311.3
Steam	195.5	195.5
Air pressure	5.5	5.
Vacuum	25.	25.
M.P Receiver	75.	55.
L.P. "	15.	15.
I.H.P, H.P.	1216.29	1248.02
" M.P.	1548.72	1323.03
" L.P Nº 1.	599.95	595.34
" L.P Nº 2.	729.17	655.33

	Stbd.
Revolutions	318.1
Steam	206.
Air pressure	F- 5.4
Vaccuum	25.5
M.P Receiver	78.
L.P. "	15.
I.H.P, H.P.	1051.9
" M.P.	1304.2
" L.P Nº 1.	547
" L.P Nº 2.	490.4

Whipple.

Cards Nº 8.

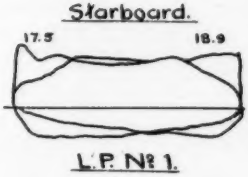
Port.



Worden.

Cards Nº 7.

Starboard.



Por

do Boats Truxtun. Whipple and Worden.

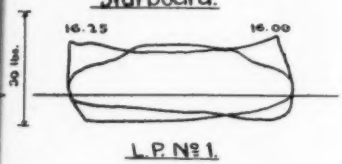
	Stbd.	Port.
	318.1	317.2
	206.	203.5
	F- 5.4	A- 5.75
	25.5	25.3
	78.	83.
	15.	10.8
	1051.92	1178.27
	1304.21	1403.61
	547 04	748.94
	490.45	564 30

	Stbd.
Revolutions	323.8
Steam	200.
Air pressure	F- 5.5
Vacuum	22.5
M.P. Receiver	41.
L.P. "	15.
I.H.P. H.P.	1228.46
" M.P.	1481.49
" L.P. Nº 1.	706.61
" L.P. Nº 2.	731.45

Truxtun.

Cards Nº 10.

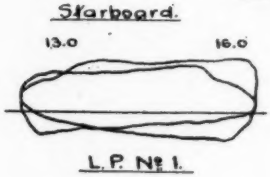
Starboard.



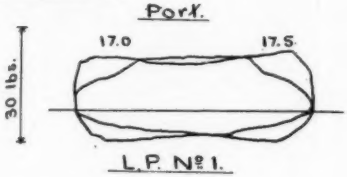
Whipple.

Cards Nº 8.

Starboard.



Port.



Maximum Cards of Torpedo Boats Truxtun, Whipple and

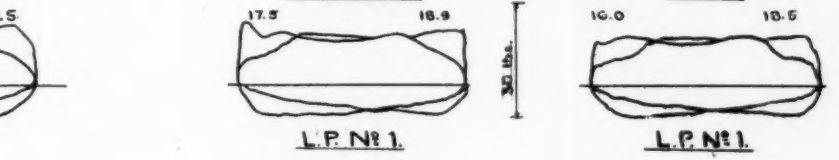
	Port.	Stbd.
	311.3	311.3
	195.5	195.5
	5.5	5.
	25.	25.
	75.	55.
	15.	15.
	1216.29	1248.02
	1548.72	1323.03
	599.95	595.34
	729.17	655.33

	Stbd.	Port.
Revolutions	318.1	317.2
Steam	206.	203.5
Air pressure	F- 5.4	A- 5.75
Vaccuum	25.5	25.3
M.P. Receiver	78.	83.
L.P. "	15.	10.8
I.H.P. H.P.	1051.92	1178.27
" M.P.	1304.21	1403.61
" L.P. Nº 1.	547 04	748.94
" L.P. Nº 2.	490.45	564.30

Worden.

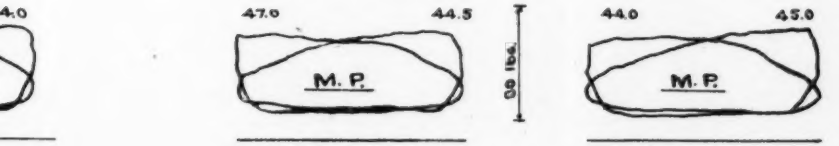
Cards №7.

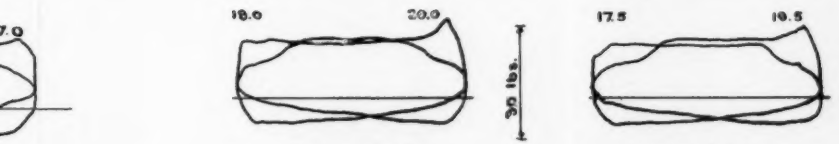
Starboard. Port.



L.P. №1. L.P. №1.

H.P. H.P.





L.P. №2. L.P. №2.

hipple and Worden.

	Strbd.	Port.
Revolutions	323.8	314.2
Steam	200.	200.
Air pressure	F-5.5	A-5.5
Vacuum	22.5	25.
M.P. Receiver	41.	75.
L.P. "	15.	14.
I.H.P. H.P.	1228.46	1206.27
" M.P.	1481.49	1398.19
" L.P. №1.	706.61	642.81
" L.P. №2.	731.45	689.39

TABLE K.

STANDARDIZATION TRIAL OF U. S. TORPEDO-BOAT DESTROYER *WORDEN* ON BARREN ISLAND COURSE, CHESAPEAKE BAY, MD., SEPTEMBER 11, 1902.

.....	First double run.		Second double run.		Third double run.		Fourth double run.		Fifth double run.	
Direction of run	S.	N.	S.	N.	S.	N.	S.	N.	S.	N.
Duration of run, minutes and seconds	2 30·4	2 34·0	2 18·0	2 22·8	2 10·8	2 14·5	2 03·7	2 06·7	1 58·0	2 03·2
Speed, knots	23.936	23.376	23.086	25.210	27.522	26.765	29.126	28.464	30.508	29.220
Mean speed during double run, knots	23.656		25.648		27.1435		28.795		29.864	
Total revolutions for each run, port engine	622	650	637	657	639	664	651	674	668	684
starboard engine	642	665	650	672	651	674	660	684	671	690
Mean revolutions per minute for double run	254.1		279.5		297.15		319.55		337.55	
apparent slip of propellers	16.15		17.34		17.72		18.84		20.31	
Steam pressure above atmosphere in engine room, main steam pipe, port	120	122	158	152	177	178	206	209	237	231
Ditto, starboard	117	122	155	151	176	177	205	207	231	227
Steam pressure above atmosphere, first receiver, port	44	45	57	56	66	66	80	78	90	88
Ditto, starboard	43	42	57	55	66	67	80	81	89	83
Steam pressure above atmosphere, second receiver, port	.8	·3	4.7	4.3	8.5	7.7	14.2	14.5	18.2	17.5
Ditto, starboard	1	·3	5	4.5	9	9.1	14.7	15.2	18	18
Vacuum, port	27	27	26.3	26.5	25.7	26	25	25	23.3	23.3
Ditto, starboard	26.8	27	26.6	26.5	26	26	25.5	25.5	24.2	23.8
Air pressure forward fire room	1	1.5	1.3	.75	2.8	2.8	5.7	6.4	7.5	6.2
after fire room	1.3	1.8	2.5	2.6	3.4	3.5	4.75	3.7	6.4	6.1
Injection	77	77	77	77	77	77	77	77	77	77
Discharge, port	107	106	111	110	114	115	118	118	125	126
starboard	105	104	105	103	110	106	107	107	117	121
Feed water, port	207	187	200	210	219	215	241	235	239	141
starboard	212	180	215	216	218	218	216	217	229	229

NOTE.—The points obtained from the observed revolutions of the engines and the corresponding speeds of the vessel on the measured mile being plotted gave very satisfactory curves, and the mean engine speed required for a speed of 26 knots of the vessel deduced from these curves was found to be 282.5 revolutions per minute.

Draught at beginning of trial, forward, feet and inches	6– 2¼
aft, feet and inches	9– 8¾
mean, feet and inches	7–11¼
Displacement, tons	492.9
Draught at end of trial, forward, feet and inches	6– 0
aft, feet and inches	9– 7
mean, feet and inches	7–9½
Displacement, tons	471.8
mean for trial, tons	482.3

The official report of the speed for one hour was 28.15 knots at an engine speed of 311.45 revolutions per minute.

ELECTRIC TRANSMISSION OF POWER FOR NAVY YARDS.—III.

By William S. Aldrich, Member.

Whether alternating or direct current shall be used entirely for factory driving in general and navy-yard transmission in particular must ever remain an open question. No just and final disposition can be made of it in the present state of the art. The advantages and disadvantages of the two systems with their very distinct types of motors are well understood. There is a sphere and a field of operation for each. There is a borderland between them in which either will serve equally well, in which alternating or direct current may be adopted at once, according to whichever system may be found in use or originally installed.

The alternating-current induction motor has the simplest electrical and mechanical construction of all types of machines. If it is of the short-circuited or "squirrel-cage" armature type, the revolving part or rotor is entirely self-contained, with no external connections, and therefore it requires no commutator or brushes. It inherently possesses small starting torque per ampère, requires a large starting current, operates at practically a constant speed, and, owing to the structural requirements for most efficient working, it must have very small clearance between the rotating and fixed parts. It operates a pronounced inductive load on the circuit, having a power factor (ratio of true to apparent energy) anywhere below unity, according to what is demanded of it. Under unguarded conditions of starting or of control (especially if of the squirrel-cage type) it may produce serious disturbances on a lighting system fed from the same mains.

The direct-current motor, of the shunt type for constant potential supply, as now used almost exclusively for machine driving, admits of ready and economic speed variation and control, pos-

sesses unity power factor, and, it is believed, produces less disturbance on other portions of the supply circuits as for lighting.

The above are only a few of the salient features upon which arguments, pro and con, have been and will continue to be adduced to prove the superiority of the one or the other type for factory driving. The distinctions are vital. The differences at present are commercially insurmountable.

Modern industrial applications of electricity have entered few more conservative fields than the domain of the workshop and the mill. Where there is overlapping of interest or of work that might profitably be adjusted, to the mutual advantage of maker and user, there has been constant effort to evade the responsibility of a change, to steer clear of the question of the adaptation of old machines to new methods of driving. Builders prefer to construct machines as they have in the past. A few purchasers, an increasing number, prefer to operate them by electricity as the future seems to indicate. The net result has been a degree of uncertainty in exploiting electric transmission in this field. It takes time to change patterns as well as ideas. Some are waiting for the specially-designed direct-connected individual-motor machine to be perfected. Others are forging ahead with electric driving with such machines as are now on the market. It is probably this condition, as much as any other, that has accelerated the installation of electric driving by constant-speed motors for standard machines and tools. Individual motors are specially desirable for large tools, much used in naval and marine work with intermittent use, yet with frequent demand for rush work. On this account it is not even necessary nor desirable to observe the 5-H.P. limit for the installation of individual motors.

Direct-current motors are now made with over 200 per cent. variation in speed with the same horsepower at any speed, and reasonably high efficiency at all speeds within this range, at any point of which the speed may be maintained constant. A direct-current motor for given work, at minimum speed, should be installed of at least one-third greater capacity than for that required at the maximum speed. In general a given direct-current vari-

able speed motor, of which the normal speed is to be the minimum called for, should not be loaded at maximum speed for an output greater than its normal capacity multiplied by the ratio of minimum to maximum speed.

The question of alternating or of direct-current motors for driving machine tools, resolves itself into deciding whether a constant or variable speed is desired for the main spindle of the machine during any one given operation. The advocates of electric driving are divided into two contending but not hostile factions.

The one party would drive machine tools, as they have been driven in the past, from constant-speed belted countershaft. For this they would now substitute a constant-speed motor. It would be preferably of the alternating-current induction type. All adjustments of speed would be made, as usual and as formerly, through the change gear and speed cones of the original machine. The induction motor would be attached to the machine for individual driving, or arranged to drive a number of machines by a sectional shaft on the group system.

The other party would equip each machine tool with a variable-speed motor. It would be preferably of the direct-current type. Its wide and economic range of speed control would serve all the purposes of the earlier change gear and speed cones, which are in such instances to be abolished.

Whatever the merits and demerits in theory, the conditions confronting the American machine-tool maker and user alike, are the modern requirements for standardization, interchangeability and adaptability. The machine builder, if paid for it, will make to order anything in his line, or out of it, for that matter, if he has time to depart from the manufacture of his standard line of production. He will build a gearless, beltless lathe, planer, shaper, drill-press, milling or boring machine, if the purchaser wishes it and will pay for it. The purchaser will have to provide additionally a variable-speed motor equipment.

Notwithstanding, the builder urges, and wisely, the purchase and use of his well-known standard line of machines. They have interchangeable elements and effective speed-change mech-

anisms sufficient for all ordinary uses of the machine. It is therefore equally adapted to be driven by a constant-speed belt or a constant-speed motor.

Old-time standards for machine-tool design will continue in evidence as long as purchasers cling to belts. These are still much used on all types of machines, even during the rapid evolution now in progress. It will no doubt be many years before builders depart finally from the precedent established by belt driving. As long as such machines are in demand they will be supplied. Not till the electric supersedes the belt drive may we expect any radical departure in this branch of machine construction.

These considerations have weighed heavily in the balance between the adoption for individual electric drive, of constant-speed motor for standard machines, or variable-speed direct-current motors for specially designed machines.

It is unnecessary to advocate further conservatism on the part of the Government. However, in the material equipment of a navy yard it is as well to adhere to interchangeable standards for machines and tools as for electric motors to drive them. Such an equipment will be best adapted to any line of work by either method of driving, should a change become necessary from present belt drive to prospective electric drive. Of all machine-tool users the Government can least afford to experiment with new and untried designs. During a public emergency such machines may be unduly taxed or overloaded, with no existing opportunity to replace them or any of their specially designed parts.

Machine tools to be driven by induction motors present an entirely different problem from that for electric traction, elevators, cranes and similar service. The latter demands frequent stopping and always starting under the maximum heavy load for that run. On the other hand, while machine tools are frequently started and stopped, they do not require to be started under the maximum heavy load for any given operation. On the contrary, they are almost universally started under lightly loaded conditions.

Moreover, the speed for cutting or other productive operation is adjusted before starting and remains constant through the operation. The run of a motor for traction, elevator and crane service is made at a continuously varying speed during the operation. This distinction between the two classes of speed requirements is vital and important. It admits of constant-speed induction motors for machine tools and well nigh prohibits their similar direct-connected use for traction and crane service. For shears, rolls, punches and like workshop appliances the induction motor seems to be all that is desired. This is especially the case when we consider its ability to stand heavy and sudden overloads, even to the point of being completely stalled.

Induction motors are especially suited for group driving. Only in a few instances are they unsuited for individual driving; namely, for those machine tools requiring a variable speed during their cutting or other operations. If the question of economy be considered, the group system will probably show better than the individual drive only where all of the machines are equally operated at the same time under their maximum loads. With light or variable loads individual motors may prove more economical. The first cost of installation for individual motors will be from two to five per cent. higher, all things considered, than for the group system, with its shafts, hangers and belts. The small individual motors are less efficient than the large group motors at the same proportional part of their normal load. They also increase the aggregate power capacity of the generating plant, for each individual motor must have sufficient capacity to carry the maximum load of its own machine.

The discussion of an alternating-current system for navy-yard transmission involves questions of phase, voltage, frequency and system of wiring. While two and three-phase systems have been very fully perfected for motor service, the single-phase system is now beginning to receive the attention it deserves from its simplicity of wiring being equal to that of the direct-current system. Nevertheless, the economy in the use of copper is on the side of the polyphase system. For the same conditions of service, the direct-current, the single-phase two-wire, and the

two-phase four-wire systems each require the same amount of copper. But the three-phase three-wire, and the three-phase four-wire require respectively 75 per cent. and 33.3 per cent. of the amount of copper of any one of the preceding two-wire systems. In such a large network of wiring as a navy yard this saving means considerable.

The early and staple objections against the use of alternating current for factory service gathered about the number of wires, for the polyphase system was chiefly advocated and the single-phase system had not yet been perfected. But, with the extension of the three-wire system into direct-current factory transmission, and very soon thereafter the adoption of the direct-current multi-voltage system, with at least four wires, almost all of these objections fell to the ground. The three-wire direct-current system brought the copper down to about 37.5 per cent. of that required by the two-wire system, and the multi-voltage system made possible successful operation at wide ranges of speeds without wasteful resistances for control.

In the matter of polyphase systems the battle still wages between two and three-phase service. Whatever be adopted there should be no transformation of voltage, phase or frequency, within the navy-yard system, unless required by some special service. Both types of polyphase service must be operated at all times well balanced. For the induction motors seek to correct any unbalancing of the system, transferring energy from the under to the overloaded side, resulting in overheating of their windings.

The three-phase system has a unique feature in permitting of two efficient working voltages without transformation by the use of the neutral wire with star grouping. The invariable relation being that of 1.73 to 1.00 between the separate outer wires (or mains) and between any one main and the neutral, it will be seen that 200-volt motors may be used, connected across the mains, and 115-volt lamps between the mains and neutral; or, 400-volt motors and 230-volt lamps respectively. Equality and independence of regulation are obtained by using the fourth or neutral wire, with better copper economy, than in either the

three-phase three-wire or two-phase four-wire systems. A polyphase system would certainly be indicated for navy-yard installation if it appeared at all likely that a distant source of electrical supply would have to be depended upon at any time.

The generator action of induction motors, due simply to overspeeding, is an incidental but desirable feature not possessed by direct-current motors. On cranes, hoists and elevators during lowering of loads, and on shears, rolls and punches on release of work, the motors will often be driven above their normal speed. This result will be almost entirely due to the inertia of the moving parts resulting in the so-called fly-wheel effect. The potential energy of this action is ultimately consumed in driving the induction motor above its normal speed and very probably above its synchronous speed.

The induction motor begins to return energy to the line or system when from any cause such as above explained it is driven by an external source of power at a speed above synchronism; that is, at a speed above that at which it is in exact synchronism with the generator of the power plant. Under such a condition the induction motor is really operating as an inductor alternator. It continues thus to operate as long as its speed is above synchronism. It ceases at the instant its speed falls below that point, although the motor may be running above its normal speed. Under no conditions in service does this type of motor attain its ideal synchronous speed. From a condition of least slip, at no load, the motor speed slips farther behind that of synchronism with the generator with every increase of load.

These phenomena are well illustrated in the case of heavy punches, shears or rolls driven by induction motors. Upon feeding in the work the motor drops in speed momentarily, but tends quickly to regain its normal speed for that load. A sudden release of the load on completing the operation causes the mechanical inertia of the rotating parts to speed the motor above synchronism. It now operates as a generator till sufficient energy is consumed to bring the speed below synchronism. The action is thus entirely automatic and beneficial. The

machines quickly return to normal speed and meanwhile have turned a little energy back into the line, and to that extent have relieved the main generators. Similar conditions may arise at any time in case of an induction motor driving a section of shafting, a group of machines, or an entire shop, especially with much shafting or heavy mill machinery. With mechanical transmission or direct-current motors there is no such helpful yet automatic adjustment of the energy relations at all times and under all loads and speeds. The direct-current motor cannot thus return energy back into the line. It will not operate as a generator upon any change of speed, but only upon reversal of its direction of rotation. This condition is not that in evidence in shop transmission.

The effect of variation in speed of the driving engine will be marked with induction-motor service, but not unfavorably; in fact, no more unfavorably than it would be in the case of a fly-wheel, to which the interchange of energy relations consequent upon speed variations in the induction-motor service is analogous. These motors will slip from four to six per cent. below their synchronous speed, under heavy loads. Therefore, such a service that is heavily loaded, before it can turn back energy into the line, must produce a greater speed change in the driving engine than in a service lightly loaded. The phenomenon depends upon how near the synchronous speed the induction motor may be when the engine changes speed. Under light loads the service may easily be changed from consumer to producer, being at that time always close to the speed of the engine.

The fly-wheel effect of an induction-motor service may be called into requisition at any time. Analogous to mechanical inertia it is effective on change of speed in either direction. It is always a desirable steadying factor to be reckoned with. If the engine momentarily slows down, the stable conditions of running have a tendency to be maintained by the induction motors approaching or exceeding the synchronous speed, when they will act as generators, returning energy to the line. Should the engine momentarily speed up the induction motors will still have

a tendency to maintain stable running conditions, as a fly-wheel would, acting as an effective check upon any sudden increase of speed by requiring and consuming more power than is merely demanded by the work at that instant.

The starting conditions of induction motors are unique. They require from one-half to several times the full load current, according to the method of starting them. Notwithstanding they develop from 1.5 to 3.5 times the normal running torque there is very small starting torque per ampère. Direct-current motors have been built to develop at starting from four to six times their normal running torque, and from two to three times their full load torque.

An instance of how starting arrangements materially affect the rush of starting current may be noted in case of a 75-H.P., three-phase, 600-volt induction motor in factory service, driving sectional shafting on group system, with a probable power factor of 90 per cent. and an efficiency of 92 per cent. The motor started with an initial rush of current of 300 per cent. above normal load, by use of water rheostat. When the motor was thrown directly across the three-phase line its starting current indicated a momentary overload of 800 per cent. Such a condition exists for only a short interval. Nothing in the motor in way of brushes or other contacts can be injured by it. Nor are there any mechanical strains to be affected by such overloads. The only disadvantage likely to arise is the voltage drop on the lighting circuits. This may be minimized by using the four-wire system for the three-phase distribution, with proper starting devices. In fact, specifications for factory motors of the induction type have been successfully met on condition that they endure being stalled absolutely for a definite time, as one minute. The maximum efficiency occurs at about 75 cent. of full load.

The shop circuits for alternating-current service must be designed and installed with some regard for the starting characteristics of induction motors. If frequent starting is not necessary, as in case of motor driving a group of machines, then the squirrel-cage or short-circuited armature type of motor will answer very well. Otherwise some one of the standard starting devices

should be used, according to the circuits being operated and the character of work to be done by the machine.

For navy-yard installations, with induction motors from 20 to 100 H.P. or over, starting will be simplified by the use of non-inductive resistances as water rheostats, for other than individual motors or machines. Such a starting resistance improves the power factor of the starting current and is entirely reliable in operation. On the other hand, rheostats in the secondary, or rotating part of induction motors have been successfully used, with as many steps as necessary to keep down the voltage fluctuations. In this respect they are similar to starting arrangements for direct-current motors. An extension of this method has been developed for producing a variable-speed induction motor.

Variations in the speed of induction motors may be affected by varying the resistance of the secondary or rotating part. One method is to provide, instead of the usual short-circuited squirrel-cage winding for the rotating part, a regular winding connected up for three-phase star grouping with terminals brought out to collector rings. From these rings wires are run to controller resistances, by operation of which the speed may be varied at will. The lower speeds are obtained with much of the resistance in on the secondary circuit, thereby dissipating the heat exterior to the rotating part. The maximum speed is, of course, obtained, with all of the external resistance out of the secondary, when the operation is the same as the simple squirrel-cage type. To obtain only two or three changes of speeds, and to run continuously at those speeds, a system of series and parallel connections of the primary stationary windings has been devised and used successfully. In this way the number of poles is altered according to the speed changes desired, and lower speeds are obtained at better efficiencies. This is especially the case where low frequencies are in use, as in factory transmission, from 25 to 40 cycles per second being the usual range. The revolutions per minute are equal to the number of cycles per second multiplied by 60, and divided by half the number of poles.

In a large installation, as in navy-yard work, where induction motors are installed, it is possible to start and stop all depart-

ments of shops with the main engine of the generating plant. The same is true where the group or sectional system is similarly driven. All such shafting may be controlled entirely from the main engine, as though it were belted directly to it. The several induction motors are left permanently in the circuit, occupying a relation to the system analogous to belt and pulley. All of the motors speed up in turn with the engine and generator, running almost at their corresponding synchronous speed, and therefore economically. The current slowly rises in value to meet the load that may be on the motors. They require no more current at any lower speed than that necessary to drive the load upon them at full speed. From the throttle and simultaneously with the engine, the whole system may be started by this method, which is now in very successful use in polyphase factory transmission. The engine is brought up to speed in about one minute, with the generators fully excited before the engine is started, and maintained so during the starting operation.

Indirect methods of electrical supply and distribution have little to commend them for navy-yard use. The accumulator has been advocated for yard traction, in preference to the trolley. But with efficient and working surface-contact systems it seems hardly necessary to bear the trouble and expense of handling storage batteries for such service, especially in war time. Still the accumulator may render valuable service in balancing sets for direct-current three-wire system, and as equalizers where the character of the loads are exceedingly variable, similar to the conditions found in traction work. Transformers have specific uses, as in electric welding and annealing, but would not be installed for the general transmission system. This, as we have seen, had best be operated at one voltage within the yard, from generator to motor. Rotary converters will be required in any double-current service, which, however, seems to be but a temporary expedient till the perfection of the alternating-current system for all service. The mixed or combination systems, with both alternating and direct current, require further complications in wiring, either of which can boast of its best results only when using four wires. No alternating-current systems require

more than four wires, no multi-voltage system can give a reasonable range of speeds with less.

The determination of the system of electric transmission and the selection of apparatus for navy-yard equipment constitute an engineering problem of the first order. It is not the least simplified by the naval exigencies of the public service, which may arise at any time in any one yard or in all of them. The character of the installation as a whole is more of a determining factor than the ultimate use of the motor load. In the case of a navy-yard drive it may be much more important to decide upon the system than to be controlled by the motor; for in such installations the motor is only one of the many and varied uses for which the electric energy will be employed.

Electricity is the most general agent for such a distributing system. With the fewest exceptions noted, it may be used for almost all of the purposes for which steam, compressed air and hydraulic power earlier found extensive application. It is in these fields that the electric motor has made the greatest inroads. Its introduction contributes most to an effective organization and arrangement of shops and departments. It promotes that individuality in the design of each shop so necessary for its highest functions.

The aims in the navy yard, as in manufacturing plants, in reorganization or in new designs, are to secure the best results at once, not expecting that some future occasion should make the equipment more effective or more economical. Hence, the extension of the system in such a well-designed plant would mean little more than adding duplicate units or parts to the existing installation. At each and every stage of such an evolution the equipment is then as complete as a system of units can be. It is always complete in itself, however far it may be developed. To this extent, therefore, it is to be considered a finished installation. As applied to the navy yard, the problem is quite similar to that of a large manufacturing plant covering several acres. Reduced to its final analysis, it is the substitution of wires for piping between buildings, departments or shops,

of electric motors for an engine in each shop so served, while the main and counter shafts may be, in special cases, retained and divided into economic sectional lengths.

The introduction of electric driving into navy-yard work comes after pronounced success in modern and modernized shipbuilding plants at home and abroad. Its flexibility and convenience alone have warranted its introduction in private establishments, and none the less so in the scattered and varied work of the modern ship yard. Compressed air has worked its way very effectively into all shipbuilding yards for the smaller and portable tools, for light and high-speed operations, such as drilling, chipping, caulking, riveting. It seems preeminently fitted for these lines of work requiring reciprocating movements, far better, in fact, than similar electric-driven tools, as far as they have been perfected. For large work, steady and heavy pressures, as in forging and flanging, hydraulic pressure offers the best service. Practically opposite to the field occupied by compressed air, there is no early probability of its being invaded by electricity. There is an evenness and smoothness in all such hydraulic operations which are chiefly of the reciprocating or plunger type. There is equal smoothness and uniformity of operation to the electric drive, but so far it is confined primarily to producing rotary motion. The requirements of modern methods of shop production have been more completely met by electricity than by any other agent.

The time has come when it no longer is recommended to repair the old hulks which served so well a past generation. May it not be now the time to do the work for the new navy with new systems and methods? It is inevitable but that there will be some loss. Will there not be a greater gain, an added prestige, a maintenance of such sea power as we have, when the time comes to prove our claim to it? To discard the antique and the obsolete has always been very difficult for the Government. The people object to such wilful waste, as in their own municipal plants. There are many instances of cities which are at least ten years behind the times in the matter of producing electric energy for the taxpayers, while private companies in ad-

joining towns furnish a better and cheaper service by more modern methods and equipment.

What manufacturer, in changing his product from wood to steel, would retain for years the equipment suited only to the old output? Granted that he might see the folly of such a course, others there are who cannot see why, with new tools and old system of power transmission, they do not get the orders. If the American people are coming to want the best for their money, which they seem to be getting in their new Navy, why should they not expect the same ashore as afloat, in navy yard as on naval vessel?

Afloat the transition has been from wood to iron, from iron to steel, for the material of construction. The motive power has changed from sail to steam. Ashore, provision must in time be made for handling the new type of naval repairs by new appliances and methods. The navy yard is destined to become transformed in aim and scope by the very necessities of the work it is now called upon to do, not to speak of the task it will have in hand, when engaging to build a battleship, against the skill, methods and appliances of several efficient private concerns. The equipment of the navy yard undergoes continual change, but always lags much behind the progress of private ship yards, whose competition for Government work is so keen and whose battleships have now earned the respect of nations.

U. S. BATTLESHIP *MAINE.*

By LIEUTENANT D. S. MAHONY, U. S. N., MEMBER.

The *Maine* is a twin-screw, armored battleship built by William Cramp and Sons' Ship and Engine Building Co. The contract was signed October 1, 1898, and the keel laid February 15, 1899, one year after the sinking of the U. S. S. *Maine* in the harbor of Havana, Cuba; the price being $2,885,000, and the time allowed for completion thirty-two months. The price stated above does not include the armor and armor bolts (exclusive of the requirements of the protective deck), the ordnance and ordnance outfit and certain articles, as anchors and chains, supplied by the Government, but does include the fitting and installing of the above. The speed guaranteed was eighteen knots per hour, to be maintained successfully for four consecutive hours, the air pressure in the fire rooms not to exceed an average of one inch of water, the vessel to be weighted to a mean draught of 23 feet 6 inches. If the speed fell below eighteen knots, the contract inflicted a penalty at the rate of $25,000 per quarter knot for speeds between eighteen and seventeen and one-half knots, and $50,000 per quarter knot for speeds between seventeen and one-half and seventeen knots. In case the speed fell below seventeen knots, it was to be optional with the Secretary of the Navy to reject the vessel or accept her at a reduced price.

HULL.

Length between perpendiculars, feet	388
on L.W.L., feet	388
over all, feet	394
Beam, extreme, feet and inches	72- 2½
at L.W.L., feet and inches	72- 2½
Ratio of length to beam	5.44
Depth (molded), feet and inches, main deck	34- 6½
upper deck	42- 6½

Height, flying bridge above main deck, feet and inches	32– 6
Draught, normal, forward, feet and inches	23– 6
aft, feet and inches	23– 6
mean, feet and inches	23– 6
Displacement, load draught (23′–10¼″), tons	12,585
normal draught (23′–6″), tons	12,370
per inch at L.W.L., tons	50.6
Area midship section to L.W.L., square feet	1,610
L.W.L. plane (22′–6″), square feet	21,083.9
Center of gravity of L.W.L. plane, aft of M.S., feet and inches	4– 6
buoyancy above bottom of keel, feet and inches	12–10¼
aft of M.S., feet and inches	0– ⅛
gravity above bottom of keel, feet	25.24
Transverse metacenter above center of buoyancy, feet and inches	17– 2½
Longitudinal metacenter above center of buoyancy, feet	420
Coefficient of fineness block	.654
of M.S.	.946
L.W.L.	.759
Cylindrical coefficient	.691
Number of frames	98
watertight compartments	293

The hull is of basic open-hearth steel, of domestic manufacture, with frames spaced 4 feet apart, except where intermediate frames are required, from the stem to frame 76; from this point aft the frames to be spaced 3½ feet.

The ship is divided into 293 watertight compartments, 17 of which are in the double bottom. The double bottom proper extends from frame 31 to frame 66. Forward and aft of these points, or throughout the limits of the magazines, the bottom plating of the magazines will form a continuation of the inner bottom; in the shaft alleys the plating continues to frame 77. A cofferdam 36 inches wide is constructed between the berth and protective decks on each side of the vessel, extending from the diagonal armor bulkheads to the ends of the vessel.

The cofferdams are filled with fire-proofed corn-pith cellulose, made in suitable briquettes, and compressed to a density of from 8 to 9 pounds per cubic foot. All wood used in the construction of the vessel is fire-proofed, and the use of wood avoided as far as possible. The upper decks and main deck, outside of the superstructure, are laid with wood, the others are covered with linoleum.

Main Deck.—On the main deck is located the six-inch battery in broadside with splinter bulkheads between the guns. On this deck are located also the crew's water closets and showers, ordnance and pay offices, drying rooms, junior officers' and warrant officers' quarters, and armory.

Berth Deck.—On this deck are the quarters of the admiral, captain and officers, the ward-room dining room, berthing space for part of the crew, the refrigerating plant, sick bay, dispensary, blower rooms, lavatories, and coal bunkers above the protective deck, and engineers' workshop.

Splinter and Platform Decks and Hold.—Below the protective deck are the machinery spaces, dynamo rooms, coal bunkers, holds, chain lockers, trimming tanks, store rooms, magazines, shell rooms, two blower rooms, communication room, steering gear, air compressors and ammunition hoists.

Drainage System.—The main drain pipe is of galvanized steel, 14 inches in diameter, and runs from the forward boiler rooms to the engine rooms, above the double bottom. It is fitted with stop-check valves in boiler and engine room, all worked from the berth deck. The suction pipes leading from the valves in the boiler rooms do not dip into drainage wells, but have their mouths located as low down as practicable, and covered with coarse strainers. The main drain pipe connects with the main circulating pumps, and with the principal steam pumps other than the feed and water-service pumps.

For the auxiliary drainage system manifolds are fitted in convenient locations throughout the machinery space, with suction pipes leading to the principal lower compartments of the ship, double-bottom compartments and trimming tanks, with connections to the sea as required. Where these pipes drain water from compartments above the double bottom a small well is fitted, projecting six inches below the inner bottom and covered by a plate strainer. All manifold valves are worked only from the manifolds. A 5-inch drain pipe connects the forward and after-manifolds, with flanges for pump connections. In the boiler and engine compartments the suctions are fitted with flanges for a direct connection to the pumps in that compartment, and the crank pits are drained independently of the rest of the bilge.

The compartments above the protective deck are drained by scuppers or portable pumps. The coal bunkers below the protective deck are drained by their own vertical sliding doors.

ARMOR.

The armor consists of a side belt of Harveyized nickel-steel, extending 3 feet 6 inches above and 4 feet below the 23½-foot load line. The thickness amidships is 16½ inches at the top and 9½ inches at the armor shelf. The maximum thickness of this side belt is maintained from the after barbette, where it begins, to the forward coal-bunker bulkhead, tapering to 10½ inches at the center line of the forward barbettes, thence to 4 inches in a length of 30 feet, which thickness is maintained to the bow. The diagonal armor extends from the slopes of the protective deck to the top of the armor belt at the forward and after ends of the machinery spaces, 12 inches thick. Above the side belt is the casemate armor, 5½ inches thick, worked from the center line of the forward barbette to the center line of the after barbette. The ends of this belt will be formed by diagonal armor 5½ inches thick, worked from the sides of the vessel to the barbette armor. The superstructure armor is 5½ inches thick. The protective deck is 2¾ inches thick between the armor bulkheads. On the side slopes at the extremities the protective deck is 3 inches thick forward and 4 inches thick aft; amidships it is 1¾ inches thick except over the steering engine where it is 3 inches thick.

ORDNANCE.

Main Battery.

4 12-inch breech-loading rifles.
16 6-inch rapid-fire guns.

Secondary Battery.

6 3-inch rapid-fire guns.
8 3-lb. rapid-fire guns.
2 1-lb. rapid-fire guns.
4 1-lb. automatic rapid-fire guns.
2 Colt machine guns.
2 3-inch field pieces.

Torpedoes.

2 submerged torpedo tubes.

MAIN ENGINES.

There are two three-cylinder triple-expansion engines of the vertical, inverted, direct-acting type, placed abreast of each other in separate watertight compartments, the H.P. cylinders being forward. Each cylinder is supported by one cast-steel inverted Y frame, and two forged-steel cylindrical columns, the upper part of the Y frames on the inside being faced to secure a cast-iron guide for the crosshead. Facings are also provided for the reversing gear. The high-pressure valve is of the double-ported piston type, of cast iron and made without packing rings. The intermediate and low-pressure valves, of cast iron, are hollow piston valves, with follower and packing ring. The high-pressure cylinder has one valve, the intermediate two, and the low-pressure four. The valves are provided with balance pistons, the cylinders of which form part of the upper covers of the valve chests. The valve gear is of the Stephenson type, with double-bar links. There is one crosshead for the intermediate-pressure and two for the low-pressure valve stems. Independent adjustable cut-off blocks are fitted to each link, with a range from .5 to .7 of the stroke. There are no starting valves on the cylinders, provision being made for starting the engines by admitting live steam to the receivers. All cylinders are steam-jacketed around the working liners and at both ends. Each engine has a 15-inch throttle valve, balanced by a piston working in a cylinder forming part of the throttle-valve casing, steam being admitted to the back of this balance piston. All steam pipes above two inches in diameter are of steel, smaller ones of copper.

The pistons are of cast steel, and conical in shape, each one fitted with two packing rings and a follower. The piston rods are hollow, of forged nickel-steel, oil tempered and annealed. The crossheads are of high-grade forged steel, each one having a wearing slipper working on guides secured to the inverted Y frames. These guides are of cast iron, and are hollow for the circulation of water. The backing guides are bolted to flanges on the go-ahead guides. The connecting rods are of forged nickel-steel, the crosshead end being forked to span the cross-

head. The eccentrics are of cast iron, each in two parts. Each backing eccentric is securely keyed on the shaft, and each go-ahead eccentric is secured to its backing eccentric by two through bolts in a slotted hole, the hole being filled up after the eccentrics are set. The eccentric straps are of cast steel, lined with white metal, and the eccentric rods of forged steel. Each engine has a steam floating-lever reversing engine, which can also be worked by a hand pump through its hydraulic control cylinder.

The turning engine is a double inverted engine, which drives, by worm gearing, a second worm, which may be made at will to mesh with a worm wheel on the propelling shaft. The turning engine shaft is squared at the end and fitted with a ratchet wrench for turning by hand.

ENGINE DATA.

Cylinders, number for each engine	3
H.P., diameter, inches	38½
I.P., diameter, inches	59
L.P., diameter, inches	92
Stroke of all pistons, inches	42
Valves, H.P. (one for each cylinder), diameter, inches	18
I.P. (two for each cylinder), diameter, inches	23
L.P. (four for each cylinder), diameter, inches	21
Valve stems, material, high-grade nickel steel, diameter, inches,	3
diameter through valve, inches	1¾
Main steam pipe, diameter at throttle, inches	15
area of cross section, square inches	276.715
Volume swept by H.P. piston, mean, per stroke, cubic feet	27.7585
I.P. piston, mean, per stroke, cubic feet	65.9120
L.P. piston, mean, per stroke, cubic feet	161.0424
Net area of M.P. to H.P. piston	2.374 to 1
L.P. to H. P. piston	5.801 to 1
Clearance of H.P. cylinder, per cent.....top, 26.95; bottom,	28.01
I.P. cylinder, per cent.....top, 18.69; bottom,	18.46
L.P. cylinder, per cent.....top, 11.9; bottom,	16.3
Piston rods, diameter, inches	7½
of axial hole, inches	3
length, feet and inches	8–11 $\frac{5}{16}$
Cylinder walls of all cylinders, thickness, inches	1½
liners of all cylinders, thickness, inches	1¾
Valve chest liners, thickness, inches	1

Jacket space, inches	¾
Cylinder relief valves, H.P. (2), diameter, inches	3½
I.P. (2), diameter, inches	3½
L.P. (4), diameter, inches	3½
Connecting rods, length, center to center, inches	84
diameter, upper end, inches	7½
lower end, inches	8½
crosshead bolts (4), diameter, inches	3½
crank-pin bolts (2), diameter, inches	4¼
Crossheads, surface (ahead), square inches	780
(backing), square inches	540
pins, diameter, inches	10½
length of pins, inches	11⅝
Crank shafts, number of sections	3
diameter, inches	16¼
of axial hole, inches	10
coupling discs, inches	29½
thickness coupling discs, inches	3¼
coupling bolts in one flange (9), diameter, inches	3⅜
journals, diameter, inches	16¼
length, inches	19¼
length of each section, feet and inches	9- 7½
maximum distance bet. journals, feet and inches	3- 5¾
pins, diameter, inches	17½
length, inches	21½
projected area, square inches	376½
diameter axial hole, inches	10½
webs, width, inches	18½
thickness, inches	10
Thrust shaft, diameter, inches	16¼
axial hole, inches	10
collars, number on each shaft	13
diameter, inches	24
thickness, inches	2
space between, inches	4
total surface, both engines, square inches,	6,032.94
length, feet and inches	14- 6½
steady bearings, inches	16
Line shafts, diameter, inches	16¼
axial hole in, inches	10
coupling discs, inches	29½
coupling bolts in one flange (9), diameter, inches	3¼
length, feet	28
Stern-tube shaft, diameter, inches	16¼
axial hole, inches	10
length, feet and inches	34- 6

Propeller shafts, diameter, inches	16¼
axial hole, inches	10
length, feet and inches	26- 7⅞
Outboard coupling, diameter, inches	30½
length, inches	17½
Strut bearing, diameter, inches	19½
length, feet and inches	4- 6½
Reversing engine, diameter of steam cylinder, inches	14
controlling cylinder, inches	7

Shafting and Bearings.—The crank shafts are of forged steel, in three interchangeable and reversible sections, with cranks at 120 degrees, and for the ahead motion follow in the order, H.P., I.P., L.P. The propeller shafts and stem-tube shafts are covered with a composition watertight casing, shrunk on and pinned. This casing will extend from the forward coupling on the stern-tube shaft to one inch inside the propeller hub. The thrust bearings are of the horse-shoe pattern, the ends and sides forming an oil trough, with a bearing lined with white metal at each end to take the weight of the shaft. The horse-shoes are of cast steel, lined with white metal, properly channeled for oil, and adjusted by brass nuts on steel side rods. There is an oil cup on top of each horse-shoe, from which an oil hole leads to each collar. At each end of each thrust bearing is a divided stuffing box and gland of brass to prevent the escape of oil. The pedestal is bolted to a cast-iron sole-plate fitted with forged-steel wedges at each end of the pedestal for adjusting the pedestal fore and aft.

Main Condenser.—There is one main condenser in each engine room. The shells are of steel, stiffened with angle bars, butted with a single butt strap on the inside, and with angle iron riveted around each end to form flanges for securing the water chests. The water chests are of composition. The water chest for the entrance and exit of the circulating water will have a division plate fitted with a valve, worked by a lever on the outside of the condenser to allow the circulating water to pass directly overboard when the valve is open. Baffle, deflecting and tube-supporting plates are fitted. The tube sheets are of rolled brass.

Diameter of shell (inside), feet and inches	6-3
Thickness of shell, inches	$\frac{3}{16}$
Length over heads, feet and inches	15-6$\frac{1}{2}$
Tubes, diameter (outside), inches	$\frac{3}{4}$
length between tube sheets, feet and inches	13-4
thickness, No. 18 B.W.G., inches	.048
number in each condenser	4,460
Condensers (2), cooling surface, square feet	19,457.36

Main Air Pumps.—For each main engine there is a Snow twin-cylinder, vertical, single-acting air pump. The air-pump casings are of composition, the steam cylinders of cast iron. The pump valves are composed of three flat discs of rolled manganese-bronze.

Diameter of steam cylinders (2), inches	14
pump cylinders (2), inches	28
Stroke, inches	18
Diameter of piston rods, inches	3
pump rods, inches	3$\frac{1}{2}$
pump valves, inches	7

Main Circulating Pumps.—For each condenser there is a centrifugal, double-inlet circulating pump, driven by compound engines with cranks at right angles to each other. The circulating pump draws water from the sea, the main drain, or the engine-room bilge, and discharges into the condenser or directly overboard. There are stop valves in the pipes leading from the sea, the main drain, and from the bilge, in each engine compartment. These valves are so connected by a locking device that when one is open the others must be shut.

Diameter of steam cylinders, inches	7 × 14
Stroke, inches	12
Diameter of pump runner, inches	54
Width of pump runner at periphery, inches	3$\frac{1}{2}$
hub, inches	7$\frac{1}{2}$
Diameter of inlet nozzle, inches	16
outlet nozzle, inches	16

Auxiliary Condensers.—In each engine room is a Wheeler auxiliary condenser with combined horizontal double-acting air and circulating pump. Shell, heads and tube plates are of com-

position. The packing and diameter and spacing of tubes are the same as in the main condensers.

Auxiliary condensers, cooling surface, both, square feet	1,717.5
Make	Wheeler
Diameter of steam cylinder of pump, inches	10
circulating-pump cylinder, inches	12
air-pump cylinder, inches	12
Stroke, common, inches	12
Air pump, kind of valve	rubber

Feed-Water Heaters.—In each engine room is a feed-water heater constructed like a condenser. The heads are of cast iron, the tubes, tube plates and tube-supporting plates of composition. The tubes are packed with corset-lacing and glands as in a condenser. Exhaust steam passing around the tubes heats the feed. The heaters are located between the feed tanks and the feed pumps, a by-pass allowing the pumps to draw from the feed tank direct. Each heater contains about 800 square feet of tube-heating surface.

Screw Propellers.—The propellers are of manganese-bronze, the starboard propeller being right-handed and the port propeller left-handed. They are true screws, with pitch adjustable from 18 to 20 feet. Each boss is accurately bored to fit the taper on the end of the shaft and fitted with a feather key, being held on the shaft by a nut screwed on and locked in place. Each boss is fitted at the after end with a composition cap bolted on watertight; bosses and caps are finished all over, tinned and smoothed.

Number of blades	3
Diameter, feet	16
of hub, inches	47½
Length of hub, inches	37
Pitch, feet	18.5
as set, feet	18
Helicoidal area, square feet	79
Projected area, square feet	63
Disc area, square feet	201.06
Pitch ÷ diameter	1.156

Boilers.—There are twenty-four Niclausse boilers, arranged in three groups, in four fire rooms, two single and two double. Each group contains eight boilers having fifteen elements of twenty-four tubes each. The boilers carry a pressure of two hundred and fifty-six pounds to the square inch. The headers are of malleable iron, rectangular in cross section, $8\frac{1}{4}$ inches by $5\frac{17}{32}$ inches inside dimensions and $\frac{5}{16}$-inch thick; the diaphragm, extending its entire length, is $\frac{5}{16}$-inch thick. The lanterns are of malleable iron, fitted to the headers with taper metal-to-metal joints. The headers are secured to the steam drums by means of a double-cone joint, ground in place and held by through bolts and nuts through a flange cast on the upper end of the headers. On the outside face of the headers are stud bolts for the chips holding the lanterns in place. The lower ends of the headers are connected with a system of blow-off piping by double-cone joints. Headers and lanterns are finished to gauge and interchangeable.

The evaporating tubes are $3\frac{1}{4}$ inches outside diameter, No. 8 B.W.G. in thickness, of cold-drawn steel. They are thickened at the ends where screwed onto the lanterns, and threaded with a left-handed thread of sixteen threads per inch. For a tight fit the tubes must be warmed before screwing them on the lanterns. At the outer ends they are reduced in diameter and fitted with a drop forged-steel cap, threaded and screwed on the tube with a taper thread of sixteen threads per inch.

The circulating tubes, 7 feet $1\frac{7}{8}$ inches long, $1\frac{19}{32}$ inches outside diameter, and No. 21 B.W.G. thick, are secured to yokes and plugs which are screwed into the lanterns. These yokes are drop forgings.

Drums and domes are of mild, open-hearth steel, the heads of the drums being strengthened by through steel braces upset at the threaded ends. To the bottom of the drum is riveted an open-hearth rolled-steel plate, $2\frac{3}{4}$ inches in thickness, and through plate and drum are conical holes to receive and make cone connections between the headers and the steam drum. Inside the steam drum are secured the feed-water box and collectors of sheet steel. A series of baffle plates in the collectors cause the precipi-

tation of any foreign matter in the feed water, and heat the feed water before it is discharged into the boiler proper. The double cones for making the joints between the headers and drums, and for the blow-off and drain connections from the bottom of the headers, are of seamless-drawn steel tubes. The taper-head bolts for the cone connections are of forged steel. On top of each header and inside of the steam drums are funnel-shaped current separators of sheet steel with malleable iron bases.

The fire fronts are of steel plates and angles, with fire and ash-pit door frames, to which are attached three fire and two ash-pit doors for each boiler. The rear end of the tubes are supported by a cast-iron plate made in sections.

Number of boilers	24
elements per boiler	15
tubes per element	24
Generating tubes, O.D., inches	3¼
length, feet and inches	7- 3.7961
gauge	No. 8 B.W.G.
Circulating tubes, O.D., inches	1.5748
length, feet and inches	7- 1.8275
gauge	No. 21 B.W.G.
Total heating surface, square feet	58,104
grate surface, square feet	1,353
Ratio of H.S. to G.S	42.94
Working pressure, pounds per square inch	256
Safety valves (24), diameter in inches	3½
Sentinel valves (24), diameter in inches	½
Smoke pipes (3), diameter, feet and inches	9-10
area, each, square feet	75.94
total	227.82
height above grates, feet	100
Escape pipes (3), diameter, inches	10

Forced Draft.—In each double fire room there are two blowers and in each single fire room one blower, designed for five hundred revolutions per minute. They deliver into the fire rooms.

Type of blower engines	Double-enclosed vertical.
Steam cylinders (2), diameter, inches	5
Stroke, inches	4
Diameter of piston rods, inches	1½
Type of blower	Sturtevant.
Diameter of fan, inches	60

Feed Pumps.—In each double fire room on the starboard side is a main feed pump capable of delivering 350 gallons per minute, and in each single fire room on this side a main feed pump of 175 gallons capacity per minute. In each port fire room is an auxiliary feed pump of the same capacity as the main feed pump in the opposite fire room. The main feed pumps take steam from both the main and auxiliary steam pipes, and may draw water from the feed tanks or feed-water heaters, discharging into the main feed pipes. The auxiliary feed pumps draw from the feed tanks, the sea, the drainage system, the fire-room bilges, or the boilers, and discharge into the fire main, boilers, or overboard through sea valves in their own compartments. The feed pumps are of the "Snow" type.

Pumps in the Engine Rooms.—In each engine room are two pumps of 400 gallons per minute capacity to be used as fire pumps with steam of eighty pounds pressure. One pump in each engine room is to draw water from the bilge or the sea and to discharge into the fire main or overboard direct; the other draws from the sea only and may discharge into the engine-room water-service pipes, into the fire main or into the distiller circulating pipes, through which it may be passed into the flushing system or overboard.

Type of pump	Duplex, single-acting, vertical.
Diameter of steam cylinders, inches	12
water cylinders, inches	7
piston rods, inches	2
Stroke, inches	12

There is also in each engine room a pump of 400 gallons per minute capacity, of light service proportions, to draw water from the filter tank and discharge it into the feed tank in the same engine room. In addition these pumps draw from the air-pump channel ways, from the sides of the ship above the water line for taking in fresh water, and from the reserve tanks.

Type of pump	Double-acting, duplex, horizontal.
Diameter of steam cylinder, inches	8
water cylinder, inches	10
piston rods, inches	$1\frac{1}{16}$
Stroke, inches	10

On each main-engine shaft is one sanitary pump and one bilge pump, each worked by an eccentric. The bilge pumps draw from the engine-room bilges and crank pits, discharging overboard. The sanitary pumps draw from the sea, and deliver into the distiller circulating pipes, overboard or into the flushing system.

Feed Tanks.—There is a feed tank of 2,000 gallons capacity in each engine room, made of ¼-inch galvanized steel, well braced internally. Each feed tank has a manhole with bolted cover, glass water gauges with guards, shut-off cocks and drain cocks, and the following pipe connections:

A discharge pipe from the air pump.

A discharge pipe from the auxiliary air pump.

An overflow pipe with spring-loaded valve to bilge.

A suction pipe to feed pumps with valve.

Drain pipes from traps.

A vapor pipe.

Each feed-pump suction is provided with a balanced valve operated by a copper float in the feed tank, so arranged that it will allow no air to enter the feed pipes.

Steam Traps.—The separators, jackets, main and auxiliary steam pipes, the radiators and all places where condensed steam can accumulate are fitted with drain pipes and cocks, or valves, with automatic traps which discharge into feed tanks. The traps have by-pass pipes and valves for convenience in overhauling.

Engineers' Workshop.—The following tools are provided: One thirty-inch screw-cutting gap-lathe, 8 feet between centers; a twenty-four-inch screw-cutting lathe, 4 feet between centers; a column-shaping machine; a double-geared drilling machine with screw feed; a small iron-column bench drilling machine for hand or power; a combined hand-punch and shears, and an emery grinder, with two wheels 12 inches in diameter and 2-inch face. These tools are driven by a vertical engine with fly-wheel, driving pulley and automatic governor.

Ash Hoists.—One ventilator in each fire room has vertical guide strips on the inside for hoisting ashes. An ash-hoisting engine

in each engine-room hatch can hoist 300 pounds from the fire-room floor to the deck in five seconds with steam of eighty pounds pressure. The engines have two cylinders with cranks at right angles; the reversing gears can be worked from the fire rooms or deck, and have safety gears to prevent overwinding.

Distilling Apparatus.—The distilling apparatus consists of four evaporators and two distillers, having a combined capacity of 8,000 gallons of potable water per twenty-four hours, at a temperature of not more than 90 degrees Fahrenheit, or 38,000 gallons for boiler feed. The evaporators will take steam from the auxiliary steam pipe.

Ice Machine.—There is one dense-air ice machine capable of producing the cooling effect of two tons of ice per day, and connected to the ice tank, the cold storage room and the scuttle butt.

Ventilation.—Two blowers operated by electricity are fitted to force air into the engine rooms. To ventilate the ship generally six blowers, arranged in groups of two and operated by electricity, are provided. These groups are used on the plenum system under ordinary conditions of service. In action the forward group may be used to force air into the forward magazines and ammunition rooms, the after group into the after magazines and handling rooms, and the midship group into the ammunition passages at the side of the vessel. Special electric blowers and pipes ventilate the dynamo room, torpedo room, steam-steering room, engineers' workshop, etc.

Windlass, Winches, Etc.—There is a windlass built by the Hyde Ship Windlass Company, situated forward on the main deck. There is a steam winch on the main deck at frame 12, and three steam winches on the bridge deck, two of them at frame 37 and one at frame 54. The ship is provided with four electric cranes.

Steering Engine.—On the after platform deck is a Williamson Bros. combined hand and steam-steering engine; diameter of cylinder 15 inches, stroke 12 inches. The engine is controlled from the conning tower and pilot house by means of hydraulic telemotor or by wire rope.

Torpedo Compressors.—There are two Rand type VI air compressors for torpedoes, driven by electricity. Each motor is shunt wound for an 80-volt current to develop 25 horsepower on 300 revolutions per minute. The compressor can deliver 20 cubic feet per hour at a pressure of 1,700 pounds per square inch.

Steam Cutters.—There are two steam cutters, one forty feet, the other thirty-six feet long. They have Ward boilers, compound engines and keel condensers.

No. of cutter.	Length.	No. of engine.	Size of engine.	Boiler, No. and type.	G.S.	H.S.	Weights, engine boiler.	
	feet.		*inches.*		*sq. ft.*	*sq. ft.*	*pounds.*	
							Eng.	Blr.
375	40	No. 303 E_2	$\frac{5 \times 10}{8}$	Ward. No. 994 G_1. round.	9.37	207	950	2,300
391	36	No. 370 G_2	$\frac{4 \times 8}{6}$	Ward. No. 955 G_1. square.	9.00	182	420	2,778

Electric Plant.—The installation consists in general of four 50-kilowatt and four 32-kilowatt generating sets, all to be of 80 volts pressure at the terminals; 770 incandescent lamps, four search lights, two sets of electric night-signaling apparatus, two diving lamps, four portable electric ventilating sets, twelve $\frac{1}{12}$-horsepower electric desk or ceiling fans, with the necessary switch boards, wire, wiring accessories, molding, conduit tubes, fixtures and lamps, instruments, tools, spare parts and stores usually furnished for the proper manipulation, test and repair of the plant.

The generating sets are secured to a common bedplate, and engines and dynamos directly connected.

DYNAMO ENGINES.

32-K.W. dynamo engines, No.	4
Type	Steepled, L.P. cylinder on top.
Diameter of cylinder, H.P., inches	9
L.P., inches	15
Stroke, inches	6
Diameter of piston rods, H.P., inches	$1\frac{7}{8}$
L.P., inches	$1\frac{7}{8}$
50-K.W. dynamo engines, No.	4

Type	Steepled, L.P. cylinder on top.
Diameter of cylinders, H.P., inches	10½
L.P., inches	18
Stroke, inches	8
Diameter of piston rods, H.P., inches	2⅛
L.P., inches	2

SPEED AND ACCEPTANCE TRIAL.

The speed and acceptance trial took place off the New England coast between Cape Ann and Cape Porpoise. The average speed after correction for tidal observations was 18 knots. There was an abundance of steam, and all parts of the machinery worked well, there being no heating of journals and very little vibration of the engines.

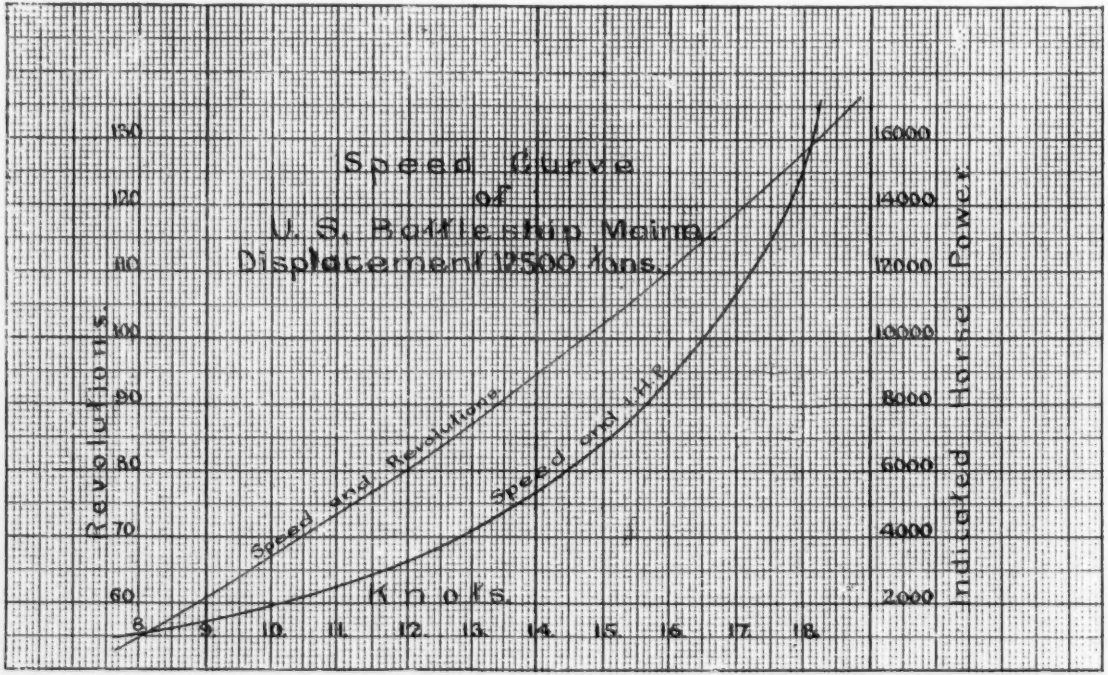
PERFORMANCE—SYNOPSIS OF STEAM LOG.

Performance:	
Steam pressure at boilers (per gauge), pounds	216
at throttle, starboard, pounds	199.6
pressure at H.P. steam chest, S. engine (per gauge), pounds,	177
at throttle, port, pounds	194
pressure at H.P. steam chest, P. engine (per gauge), pounds,	175
1st receiver, S. engine, absolute, pounds	93.4
P. engine, absolute, pounds	85.4
2d receiver, S. engine, absolute, pounds	36.1
P. engine, absolute, pounds	34.1
Vacuum in condensers, in inches of mercury P., 24.53; S.,	23.6
Mean effective pressures in cylinders in pounds per square inch:	
Main engines—Starboard, H.P.	71
1st I.P.	35.65
L.P.	16.45
Port, H.P.	70.625
1st I.P.	32.47
L.P.	15.84
Mean effective pressure, in pounds per square inch on L.P. piston, equivalent to aggregate M.E.P. on all pistons, starboard	43.31
Mean pressure, in pounds per square inch on L.P. piston, equivalent to aggregate M.E.P. on all pistons, port	41.33
Auxiliary machinery, mean effective pressures:	
Pumps—air, main, port	13.75
starboard	13.75
circulating, main, port H.P.	37.5
L.P.	10.6
starboard	Not taken.

Revolutions per minute:		
Main engines	starboard, 127.15; port,	128.84
Pumps, air	starboard, 27; port,	21.9
circulating	starboard, 205; port,	182
auxiliary	hot-well pump,	40
Blower engines, revolutions		492
Speed of ship in knots per hour		18
Slip of propeller in per cent. of its own speed, based on final pitch	S., 20.3; P.,	21.7
Air pressure in fire rooms, in inches of water		.214
Indicated horsepower:		
Main engines—starboard, H.P.		2,187.1
1st I.P.		2,607.6
L.P		2,939.7
total		7,734.4
port, H.P.		2,204.6
1st I.P.		2,406.6
L.P		3,868.3
total		7,479.5
Air pump	starboard engine, 9.95; port engine,	8.27
Circulating pump	starboard engine, 123.4; port engine,	82.36
Feed pumps	4 main, 4 aux. = 106.8 + 54.4 =	161.2
Hot-well pump	S., 5.22; P.,	5.22
Auxiliary condenser air and circulating pumps, est	S., 2; P.,	2
Water-service pumps	starboard engine, 1.81; port engine,	1.81
Blower engines, for forced draft in fire rooms	12 @ 8.85 =	106.2
Dynamo engines	1 — 50 kw. and 1 — 32 kw. =	123.9 I.H.P.
Collective of all main engines		15,213.9
main engines, air, circulating and feed pumps		15,603.08
and auxiliary engines in operation during trial,		15,840.80
all machinery during trial, per square foot of G.S.		11.715
H.S.		.2728
Main engines, air, circulating and feed pumps, per square foot of G.S.		11.531
Main engines, air, circulating and feed pumps, per square foot of H.S.		.26852

After the completion of the trial the machinery was found to be in excellent condition on the whole. A cylinder cover on a circulating-pump engine was broken by the working loose of a nut, and a few furnace-door casings were found warped. The boilers were clean and in good condition.

The steering engine worked smoothly, putting the helm from hard-a-port to hard-a-starboard in 21 seconds.


Speed Curve
of
U. S. Battleship Maine.
Displacement 12500 tons.
Revolutions
Indicated Horse Power
Knots.
Speed and Revolutions.
Speed and I.H.P.
150
120
80
100
90
80
70
60
16000
14000
12000
10000
8000
6000
4000
2000
8
9
10
11
12
13
14
15
16
17
18

GRAPHICAL CHART FOR THE SOLUTION OF VALVE-GEAR PROBLEMS.

By W. F. DURAND, MEMBER.

The solution of problems arising in the design of valve gears has usually been effected by the use of one or another of the various valve-gear diagrams which have been devised for this purpose. Of these the Zeuner and Bilgram diagrams are unquestionably the best known and most widely used. It is understood, of course, that by the use of a diagram of this character only a first approximation to the actual solution can be reached. It is all that can be expected of a diagram composed simply of straight lines and circles and involving only the elements: port opening, cut-off, lap, lead, eccentric throw and angular advance. In fact, it is readily seen that the two diagrams mentioned above are both special graphical methods for the solution of the equation connecting the elements involved, and neglecting all effects due to angularity of rods, etc. Even with this limitation, however, the Zeuner and Bilgram diagrams have been of the very highest use in connection with the study of valve gears, and serve in an admirable manner to give results which, though approximate in character, are often quite sufficient for the needs of the designer, especially in the earlier stages of his work. While it is no part of the present paper to compare the two forms of diagram, it may be noted in passing that while of equal theoretical accuracy, and while simply different methods of solving the same equation, they are not of equal applicability to all kinds of problems. For some the Zeuner is the better adapted and for others the Bilgram. It is a fact, though, that for the problem which arises most commonly, given port opening, lead and cut-off, the latter is much more readily applicable than the former. In common these dia-

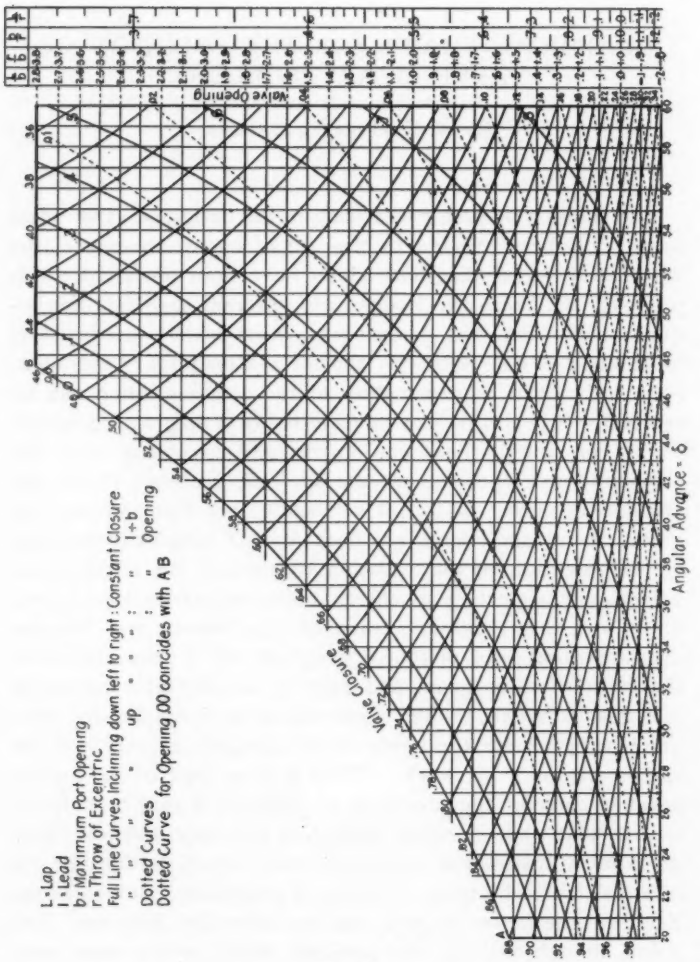

L = Lap
l = Lead
b = Maximum Port Opening
r = Throw of Excentric
Full Line Curves Inclining down left to right : Constant Closure
" " " " up " " " : " l + b
Dotted Curves " " " " Opening
Dotted Curve for Opening 00 coincides with A B
Valve Opening
Valve Closure
Angular Advance = δ

FIG. 1.

grams possess the disadvantage that the results of slight modifications in the values is not always readily seen without the construction of a new diagram. That is, each construction naturally gives the solution of a single definite case, and for a different case a corresponding construction must be made.

The purpose of the present paper is to describe a form of diagram or graphical representation of the relations involved, which, once drawn, shall contain the solution of all possible problems within the usual working range, and which shall thus present readily to the eye the results of slight modifications or adjustments in the data. With such a diagram the solution of a problem in valve gear design, at least to the same degree of accuracy as with the Zeuner or Bilgram diagrams, becomes merely a matter of reading the values desired directly from the diagram, and without any additional construction whatever.

The details of the development of the diagram are given in the appendix. The diagram is shown in figure 1.

One of the vertical scales on the right gives values of L divided by b, or lap divided by maximum port opening, or, in other words, of the lap for a maximum port opening of one inch. Other sizes are then readily found by proportion. The horizontal scale gives values of δ, the angular advance. The full line curves sloping from the left upward to the right give the relations between $L \div b$ and δ, each curve for a constant value of $l \div b$ or lead divided by maximum port opening as marked at the right hand or upper extremity. Similarly the full line curves sloping from the left downward to the right give the relations between $L \div b$ and δ, each curve for a constant value of valve closure as marked at the upper or left hand extremity. The dotted curves sloping from the left upward to the right give the relation between $L \div b$ and δ, each curve for a constant value of the valve opening is marked at the upper or right hand extremity. It will be noted that the line for opening at o, or the end of the stroke, co-incides with AB, the line for o lead. This diagram serves to answer all questions involving lap, lead, cut-off, compression, exhaust-opening, steam-opening, angular-advance and maximum port opening.

One or two examples may be given by way of illustration. Given maximum port opening 1.5 inches, lead .3 inch, cut-off 60 per cent. The lead ratio, or $l \div b$, is .3 divided by 1.5 or .2. We then simply take the curve for 60 per cent. cut-off and follow down till we meet the .2 $l \div b$ curve. This is at a point where the value of δ is about 42½ degrees, and the lap ratio is about 1.44. The lap is therefore $1.5 \times 1.44 = 2.16$, and hence the eccentric throw is $1.5 + 2.16 = 3.66$, while the angular advance is, say, 42 degrees 15 minutes as noted. The steam opening is apparently at about one-half of one per cent. before end of stroke. Now with the eccentric given, it will be more convenient for the exhaust events to relate the exhaust lap and exhaust opening to the eccentric throw as given in the two outer scales on the right. Suppose, therefore, for the exhaust lap L, we have $L \div r = .1$. Then following down vertically at the same value of $\delta = 42$ degrees 15 minutes to the level $L \div r = .1$, as given in the outer vertical scale, we find a point a little above the closure curve .84 and near the opening curve .10. As indicated, therefore, compression will be a little earlier than .84, say .835, while exhaust opening will be almost exactly at .10 before the end of the stroke. By going down to o lap we find that with this condition compression is at .87 of the stroke and release .13 before end. By making the exhaust-lap ratio negative .37 inch as indicated by lap ratio $L \div r = -.1$ we find similarly compression at about .90 and release at about .16 before end of stroke.

Suppose again in the first example that the lead is ⅜-inch $= .375$. Then the lead ratio $l \div b = .375 \div 1.5 = .25$. There is no curve corresponding to this exact value, but its location between .20 and .30 is readily estimated with all sufficient accuracy, and we find in such case $\delta =$ say 43 degrees 6 minutes and $l \div b = 1.37$.

Next given throw of eccentric 4½ inches, lap $= 2\frac{1}{2}$ angular advance $= 41$ degrees. The maximum port opening will be $4\frac{1}{2} - 2\frac{1}{2} = 2$ seconds and lap ratio degrees $2\frac{1}{2} \div 2 = 1.25$. Taking the line of angular advance $\delta = 41$ degrees, and following up to $L \div b = 1.25$ we find $l \div b = .225$ or lead $= .45$ inch and cut off $= .63 +$.

By the aid of the two scales on the extreme right, as we have just seen, the diagram may be readily used for determining the results to be obtained with a given eccentric. The quantities in the column $b \div r$ are the reciprocals of those in the adjacent column on the left and may be considered as giving values of the maximum port opening per inch of eccentric throw. Likewise the quantities in the column $L \div r$ are found by subtracting those in column $b \div r$ from 1, and may be considered as the lap per inch of eccentric throw.

Thus suppose eccentric throw 4 inches, lap $2\frac{1}{2}$ inches, angular advance 44 degrees. Then $L \div r = 2.5 \div 4 = .625$, and following to the left on this level to $\delta = 44$ degrees we find cut-off at about .565 and lead about .18 of port opening or $.18 \times (4 - 2.5) = .27$ inch.

In a similar way all other problems may be solved. The diagram also shows readily the effect of any variation in one of the stated conditions or the necessary variation in order that any particular element may remain unchanged.

Thus suppose in the first example that it were desired to keep the cut-off and lead constant, but to increase port opening to 1.7 inches. The lead ratio would then become $.30 \div 1.7 = .176$.

Following the line of .60 cut-off up to the estimated location for this lead curve, and it shows that the angular advance must be decreased to about 41 degrees 40 minutes and the lap ratio increased to about 1.48 or lap increased to $1.7 \times 1.48 = 2.516$ or eccentric throw increased to $1.7 \times 2.48 = 4.216$. In a similar way all like questions may be determined.

As noted above, the diagram gives the relations between the various quantities involved, but without any reference to the effect due to the angularity of the connecting rod, and in this respect is, of course, similar to the Zeuner and Bilgram diagrams.

This additional influence may, however, be readily represented graphically as in Fig. 2. The scales of piston position for an infinite connecting rod are shown on the vertical sides, that for the down stroke on the left, and for the up stroke on the right. The scales for the actual piston positions are shown

at top and bottom, that for the down stroke at the bottom, and for the up stroke at top. The curve then shows the relation between the two for ratios of connecting rod to crank from 4 to 5. As nearly as may be the lower edge of the curve will give the relation for a ratio of 5, the middle for a ratio of 4.5, and the upper edge for a ratio of 4.

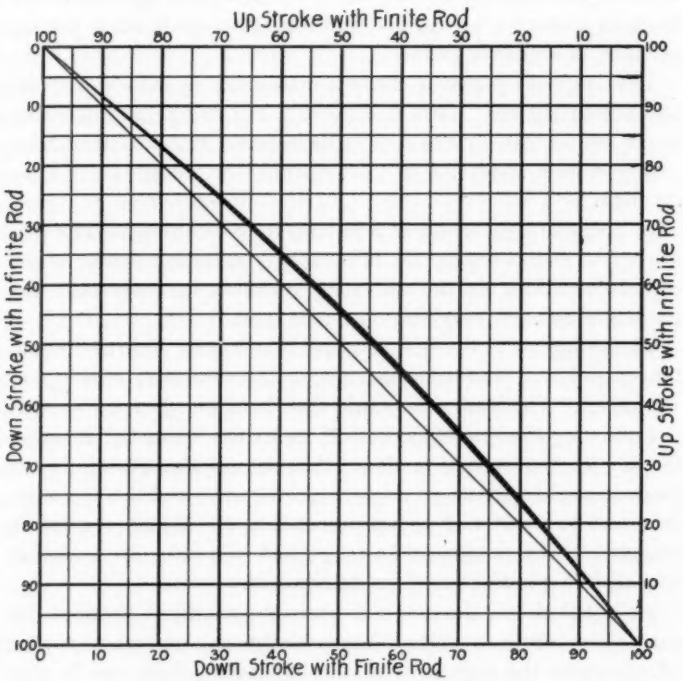

Up Stroke with Finite Rod
Down Stroke with Infinite Rod
Up Stroke with Infinite Rod
Down Stroke with Finite Rod
100 90 80 70 60 50 40 30 20 10 0
0 10 20 30 40 50 60 70 80 90 100

FIG. 2.

Thus, a crank position which would give with an infinite rod a piston position of .60 would give with a ratio of 4 a position of about .66 on the down stroke and .54 on the up stroke. Remembering that outside of the influence due to angularity of valve rods and secondary causes, the valve events are

determined by the angular positions of the crank and eccentric, it follows that we may readily, by the aid of Fig. 2, correct the results of the diagram in Fig. 1 for angularity of connecting rod. Thus, any condition which will produce with an infinite connecting rod events for piston locations, as indicated in Fig. 1, will produce the same events for different piston positions, as given in Fig. 2. Or, *vice versa*, for any desired piston position in relation to a valve event on either the up or down strokes the corresponding position with an infinite rod may be read from Fig. 2 and such position used in Fig. 1.

Thus, for illustration, in example 2 the cut-off was at .63 +. With a ratio of connecting rod to crank of 4.5 this would give about .68 on the down stroke and .58 on the up stroke. Suppose we should desire to readjust the laps at top and bottom so as to give cut-offs at say .66 on the down stroke and .60 on the up stroke. Taking the former first we find from Fig. 2 that .66 on the down stroke with a connecting-rod ratio of 4.5 corresponds to about .61 for the infinite rod. Then with the given angular advance of 41 degrees we find $L \div r = .591$ or $L = .591 \times 4.5 = 2.66$. This will be the lap for cut-off on the down stroke, or lap on top of the valve. Next for .60 on the up stroke with the connecting-rod ratio of 4.5 we find .65 for the infinite rod. Taking the value of $\delta = 41$ and this cut-off we find $L \div r = .523$ or $L = .523 + 4.5 = 2.35$. This will be the steam lap for the up stroke or on the bottom of the valve. Next, to investigate the effect of this on the lead, it is evident that the change in the lap will produce an equal but contrary change in the lead. On top the lap was increased from 2.5 to 2.66 or .16 inch. Hence the lead will be reduced by .16 inch or from .45 inch to .29 inch. On the bottom the lap was decreased from 2.5 to 2.35 or .15 inch. Hence the lead will be increased from .45 to .60. Whether such modifications in the lead are permissible must of course be determined by the special circumstances of the case in hand.

Appendix.

To develop a diagram of this character we will first deduce the equation connecting the various quantities involved, and of

which the Zeuner and Bilgram diagrams are methods of effecting a graphical solution.

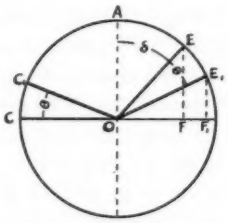


FIG. 3.

Let OC denote the crank on the center.

Let OE denote the eccentric.

Let r = the throw of the eccentric OE.

Let δ = angular advance AOE.

Then neglecting angularity of eccentric rod, the movement of the valve on either side of its own mid-position will equal the horizontal component of the movement of E on either side of the center O.

Denoting the displacement from the center by y, we have for any position of the crank C_1 determined by the angle θ, the value y represented by OF_1.

But $OF_1 = OE \sin OE_1F_1 = r \sin AOE_1$.

But $AOE_1 = (\theta + \delta)$.

Hence we have in general

$$y = r \sin (\theta + \delta).$$

Let b = maximum port opening.

Let L = steam lap.

Then $r = b + L$ and

$$y = (b + L) \sin (\theta + \delta). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Let θ_1 = crank angle at valve closure.

Then at this point $y = L$ and we have

$$L = (b + L) \sin (\theta_1 + \delta), \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

or

$$L = b \sin (\theta_1 + \delta) + L \sin (\theta_1 + \delta).$$

Divide by b and we have

$$\frac{L}{b} = \sin(\theta_1 + \delta) + \frac{L}{b}\sin(\theta_1 + \delta).$$

Whence

$$\frac{L}{b} = \frac{\sin(\theta_1 + \delta)}{1 - \sin(\theta_1 + \delta)}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Also at the end of the stroke

$$y = (L + l),\ \theta = O,$$

and we have

$$(L + l) = (L + b)\sin\delta, \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

or

$$(L + l) = L\sin\delta + b\sin\delta.$$

Divide by b and we have

$$\frac{L}{b} + \frac{l}{b} = \frac{L}{b}\sin\delta + \sin\delta.$$

Whence

$$\frac{L}{b} = \frac{\sin\delta - \frac{l}{b}}{1 - \sin\delta}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Next in regard to the displacement of the piston from the end of the stroke we have as follows:

Let x = percentage distance from end of stroke.

Let S = stroke.

Then with an infinite connecting rod, piston travel equals

$$\frac{S}{2}(1 - \cos\theta),$$

and

$$x = \frac{S}{2}(1 - \cos\theta) \div S = \frac{1 - \cos\theta}{2}. \quad . \quad . \quad . \quad (6)$$

With a given point for the valve closure, θ is found by the use of (6).

Then with a known value of δ, $\frac{L}{b}$ is found from (3).

Also for a known value of $\frac{l}{b}$, $\frac{L}{b}$ is found from (5).

The values of $\frac{L}{b}$ from (3) are then plotted on an abscissa of values of δ, each curve for a fixed value of the cut-off as shown

by the curves inclining from the left downward, while the values of $\frac{L}{b}$ from (5) are plotted on the same abscissa, each curve for a fixed value of $\frac{l}{b}$ as shown by the curves inclining from the left upward.

Also let $\theta_2 =$ crank angle at valve opening. This, estimated before the beginning of the stroke, must be taken as negative. Hence we have from (3),

$$\frac{L}{b} = \frac{\sin(\delta - \theta_2)}{1 - \sin(\delta - \theta_2)} \quad \ldots\ldots\ldots \quad (7)$$

The values of θ_2 being given, $\frac{L}{b}$ is found for a series of values of δ, thus giving the dotted curves as shown in the figure.

For the curve of Fig. 2, we have the well known approximate expression for piston displacement:

$$y = a\left(1 - \cos\theta + \frac{\sin^2\theta}{2m}\right).$$

where $y =$ displacement.
$a =$ crank.
$\theta =$ crank angle.
$m =$ ratio of connecting rod to crank.

Reducing this to a percentage of the stroke we have:

$$\frac{y}{2a} = \frac{1 - \cos\theta}{2} + \frac{\sin^2\theta}{4m}.$$

For an infinite connecting rod we have:

$$\frac{y}{2a} = \frac{1 - \cos\theta}{2}.$$

The difference is $\sin^2\theta \div 4m$ or with one per cent. as a unit the difference becomes $100 \times \sin^2\theta \div 4m$, or

$$\text{Difference} = \frac{25}{m}\sin^2\theta.$$

These differences for $m = 4, 4.5, 5$ are plotted as in Fig. 2, and the space between the curves for $m = 4$ and $m = 5$, filled in solid as shown.

STEAM YACHT *WACOUTA.*

By William A. Fairburn, Associate Member.

The steam yacht *Wacouta*, originally named *Eleanor*, was constructed by the Bath Iron Works, Bath, Maine, 1893–4. The vessel was built for William A. Slater, of Norwich, Connecticut, and was especially designed and constructed as a deep-sea cruiser for circumnavigating the globe. Her voyage around the world proved very successful, she steaming and sailing 42,406 miles in sixteen months. The yacht is barque rigged and carries an unusually large coal supply. In 1896 the *Eleanor* was chartered to various prominent yachtsmen, and in 1898 she became the property of Mrs. Cardeza, of Germantown, Pa., who, after using the vessel about two years, in turn sold to James J. Hill, of St. Paul, Minn.

The principal dimensions and features of the hull are as follows:

Length over all, feet	243
load-water line, feet	208
Molded beam, feet	32
depth at side, feet and inches	18– 5
center, feet and inches	18–11
Depth of hold, feet and inches	17– 5
Mean draught, feet and inches	12– 8
with keel, feet and inches	13– 4
Draught, aft, feet and inches	14– 2
Depth of keel, inches	8
Overhang, forward, feet and inches	19– 2
aft, feet and inches	15–10
Freeboard, forward, feet and inches	14–10½
aft, feet and inches	11– 7½
Deadrise, midships, feet and inches	4–10½
Tumble home, midships to deck, inches	5
Gross tonnage, tons	803.8
Net tonnage, tons	401.9
Displacement, tons	1,133
Coefficient of displacement	.4469
Area midship section, square feet	316

Coefficient of midship section	.7408
Prismatic coefficient	.603
Area of load-water plane, square feet	4,753
Coefficient load-water plane	.6033
Tons per inch of immersion	11.31
Center of buoyancy below L.W.L., feet	4.789
aft of midship, feet	6.058
Transverse metacenter above center of buoyancy, feet	7.654
$\frac{B^2}{d}\,x,\ x$	.0947
Longitudinal metacenter above center of buoyancy, feet	270.38
$\frac{L^2}{d}\,x,\ x$	.0791
Moment to alter trim one inch, feet tons	121.6
$\frac{L^2 b}{x},\ x$	11,385
Metacentric height, G.M., feet	2.25
Wetted surface, square feet	7,820
Ratio length to beam	6.5 to 1
depth	11.94 to 1
beam to depth	1.94 to 1
Area immersed longitudinal section, square feet	2,590
Rudder area, square feet	49.4
Ratio	52.4 to 1
Number of decks	2
Spacing of deck beams, inches	48
frames, inches	24
Number of watertight compartments	18

Deck erections, one large deck house with pilot house forward over same.

The yacht was built to conform to the requirements of the highest classification of the United States Standard Register and the American Shipmaster's Association. The building tonnage is 868.5 tons. The general scantlings are given below:

Vertical keel	31 inches wide, 17½ pounds weight per square foot.
Side-bar keel	8 inches wide, 20½ pounds weight per square foot.
Horizontal keel	20 inches wide, 15 pounds weight per square foot.
Garboard strake	47 inches wide, 20½ pounds weight per square foot.
Sheer strake	42 inches wide, 22½ pounds weight per square foot.
Remainder of shell plating	17½ pounds weight reduced to 15 pounds at ends.
Main-deck stringer plate	42 inches wide, 17½ pounds weight per square foot.
Deck plating amidships	10 pounds weight per square foot.
Lower-deck stringer plate	14 inches wide, 17½ pounds weight per square foot.
Side stringers, intercostal	12½ pounds per square foot.
Frames	3½ inches × 3 inches × 7 pounds per foot angles.

Reverse frames..... 2½ inches × 2½ inches × 4¼ pounds per foot angles.
Vertical keel and stringer angles.. 4 × 3 inches × 9 pounds per foot angles.
Main-deck beams..... 7 inches × 3 inches × 18¼ pounds per foot bulb angle.
Lower-deck beams..... 4½ inches × 3 inches × 9 pounds per foot angle.

The capacity of the coal bunkers and water tanks is as follows:

A.—Coal Bunkers.

	Tons.
Normal coal capacity	247.4
Maximum coal capacity	262.3

B.—Water Tanks.

	Gals.	*Tons.*
No. 1. Forward ballast tank	2,827	10.79
No. 2. Forward ballast tank	4,993	19.07
No. 3. Aft ballast tank	3,324	12.69
No. 4. Aft ballast tank	3,112	11.88
Forward trimming tank	2,875	10.95
Aft trimming tank	3,724	14.22
Independent fresh-water tank No. 1	1,812	6.72
Independent fresh-water tank No. 1A	1,812	6.72
Independent fresh-water tank No. 2	989	3.67
Independent fresh-water tank No. 2A	989	3.67
Independent fresh-water tank No. 3	642	2.38
Independent fresh-water tank No. 3A	642	2.38
Hot sea-water tank	600	2.29
Cold sea-water tank	600	2.29
Hot fresh-water tank	600	2.29
Cold fresh-water tank	600	2.29
Slop tank, forward	763	2.91
Slop tank, aft	737	2.81

The following are the dimensions of the yacht's spars:

Foremast step to cap	74 ft. 0 in.	Dia. 21 in.	Rake 3½°
Mainmast step to cap	77 ft. 3 in.	Dia. 21 in.	Rake 4½°
Mizzen step to cap	62 ft. 9 in.	Dia. 18 in.	Rake 6½°
Fore topmast over all	53 ft. 4 in.	Dia. 13 in.	Pole 5 ft. 0 in.
Main topmast over all	53 ft. 4 in.	Dia. 13 in.	Pole 5 ft. 0 in.
Mizzen topmast over all	46 ft. 8 in.	Dia. 10 in.	Pole 5 ft. 0 in.
Fore yard over all	64 ft. 0 in.	Dia. 13 in.	Arm 3 ft. 0 in.
Fore topsail yard over all	48 ft. 0 in.	Dia. 11 in.	Arm 2 ft. 6 in.
Fore topgallant over all	33 ft. 0 in.	Dia. 7 in.	Arm 2 ft. 6 in.
Main yard over all	64 ft. 0 in.	Dia. 13 in.	Arm 3 ft. 0 in.
Main topsail yard over all	53 ft. 4 in.	Dia. 11 in.	Arm 2 ft. 6 in.
Main topgallant yard over all	46 ft. 8 in.	Dia. 7 in.	Arm 2 ft. 6 in.
Spanker boom over all	56 ft. 0 in.	Dia. 10 in.	
gaff over all	34 ft. 6 in.	Dia. 8 in.	

Fore spencer gaff over all	18 ft. 0 in.	Dia. 6 in.
Main spencer gaff over all	18 ft. 0 in.	Dia. 6 in.
Bowsprit over all	41 ft. 6 in.	Dia. 19 in.

The fore and main mast heads are 10 feet, mizzen head 8 feet. The bowsprit is housed for a length of 10 feet. The fore and main trucks are each 110 feet above the load-water line, and the mizzen truck is 95 feet 3 inches above the same. All the spars, including the small gaffs, are made out of Oregon pine.

The sail area of the *Wacouta* is as follows:

Area.	*Square feet.*
Fore staysail	432
Jib	676
Flying jib	546
Jib topsail	410
Fore course	1,635
topsail	1,198
Fore topgallant sail	508
Main course	1,635
topsail	1,198
Main topgallant sail	508
Spanker	1,594
topsail	595
Fore spencer	814
Main spencer	814
Main topgallant staysail	527
Mizzen staysail	432
Mizzen topmast staysail	514
Total sail area	14,036

The center of effort of the twelve principal sails forward of the center of lateral resistance is 21.86 feet and 49.57 feet above the load-water line.

The displacement of the yacht loaded to the designed load line can be divided up into fixed weight and consumable weight as follows:

Complete weight of hull and machinery, tons	789
Ballast, tons	40
Total fixed weight, tons	829
Coal, tons	225
Fresh water, tons	32
Stores, tons	47
Total consumable load, tons	304
Weight or displacement, tons	1,133

The yacht was fitted originally with the following outfit of small boats, but recently an alco-vapor motor has displaced the steam machinery in the power cutter. A new alco-vapor launch has been substituted for the naphtha launch stated below, and the jib-and-mainsail racing boat has been removed.

Steam cutter:

Length, 28 feet 3 inches; beam, 7 feet; depth, 3 feet 5 inches.
Engine, 3½ by 3½ inches; revolutions, 600; steam, 170 pounds; I.H.P., 5.
Boiler, Almy water-tube; grate surface, 3 square feet; heating surface, 75 square feet; Blake air and feed pump, 3½ — 4½ — 1½ by 4 inches.
Propeller, 3-bladed, 21½ inches diameter; pitch, 18 to 21 inches.
Speed, 8 miles.
Total weight, 4,600 pounds.

	Length.	*Beam.*	*Depth.*
Naphtha launch	25 ft. 0 in.	5 ft. 4 in.	2 ft. 7 in.
Jib-and-mainsail boat	19 10½	8 1	2 3
Gig	27 11	5 0	2 3
Life boat	27 8	6 6	2 6½
Life boat	27 8	6 6	2 6½
Dinghy	13 11	4 6	2 1

The following are the sizes of the steel wire rigging of the *Wacouta:*

	Circumference wire.
Fore rigging shrouds	3 inches.
Fore topmast back stays	2¾
Fore topgallant back stays	2½
Fore stay	3¾
Jib stay	3
Flying jib stay	2¾
Fore topgallant stay	2½
Fore topmast rigging shrouds	2
Fore and main topsail lifts	2½
Topgallant lifts	2
Inner jibboom guys	3
Middle jibboom guys	2¾
Outer jibboom guys	2½
Main rigging	3
Main topmast back stays	2¾
Spring stays	3¾
Main topmast stay	3
Main topgallant stay	2¾
Main topmast rigging	2
Lower and topsail yard foot ropes	2½
Topgallant yard foot ropes	2

	Circumference wire.
Jibboom foot ropes	2¼ inches.
Mizzen rigging shrouds	2¾
Mizzen topmast back stays	2½
Mizzen stay	3¾
Mizzen topmast stay	2¾
Spanker top lifts	2½
Try sail top lifts	3

The following is the complement of the vessel: 1 captain, 3 mates, 2 boatswains, 8 sailors, 6 boys, 1 chief engineer, 2 assistant engineers, 2 oilers, 2 watertenders, 3 firemen, 3 coal passers, 1 steward, 2 assistant stewards, 2 cooks, 4 pantry boys, 1 carpenter, 2 laundrymen.

Total number of officers, 8.

Total number of petty officers, 15.

Total number of crew, 22.

Total complement, 45.

Number of berths in forward forecastle, 18.

Number of berths in compartment aft of forecastle, 18.

Number of officers' staterooms, 8.

Number of berths in officers' staterooms, 12.

Seating capacity officers' dining room, 12.

Seating capacity captain's dining room, 6.

The owner's and guests' accommodations consist of the following:

Number of state rooms, 10.

Berthing capacity state rooms, 16.

Berthing capacity servants' rooms, 4.

Number of bath rooms, 3.

Seating capacity dining room, 16.

Floor space main saloon, 315 square feet.

Floor space dining saloon, 335 square feet.

Floor space smoking saloon, 255 square feet.

Floor space social hall, 190 square feet.

Floor space owner's library, 120 square feet.

Number of private pantries, 2.

Total floor space owner and guests' living accommodation, main deck, 1,040 square feet; lower deck, 2,050; total, 3,090.

The following general dimensions pertaining to the internal and deck arrangement of the yacht may be of interest:

Length of boiler room, feet	34
forward coal bunker, feet	4
midship coal bunker, feet	8
engine room, feet	20
Total length of machinery and coal space, feet	66
Forward boiler-room bulkhead forward of midship, feet	30
Aft engine-room bulkhead aft of midship, feet	32
Foremast forward of midships at main deck, feet	56
Mainmast aft of midships at main deck, feet	10
Mizzenmast aft of midships at main deck, feet and inches	66– 3
Forward end of deck house forward of midship, feet	54
Aft end of deck house aft of midship, feet and inches	64– 6
Length of lower deck forward, feet	64
aft, feet	70
Collision bulkhead aft of forward perpendicular above lower deck, feet and inches	9– 4
Collision bulkhead aft of forward perpendicular below lower deck, feet and inches	13– 4
Length of hold No. 1, feet	24
2, feet	32
3, feet	24
4, feet	30
Stuffing-box bulkhead forward of aft perpendicular, feet	19
Length of stern tube, feet	14
screw well, feet and inches	4– 4
monkey forecastle deck, feet	19
aft end of forecastle deck to forward end of deck house, feet,	38
Floor space of galley, square feet	156
laundry, square feet	143
dry room, square feet	110

The vessel is fitted with the following armament:

2 1-pounder Driggs-Schroeder rapid-firing guns.
30 Winchester repeating rifles, No. 44 caliber.
10 Winchester repeating rifles, No. 45 caliber, heavy.
24 Colt's navy-pattern revolvers, No. 38 caliber.
30 cutlasses complete with belt.

The *Wacouta*, formerly *Eleanor*, was probably the first vessel fitted with a complete steam-laundry plant. It has been in almost constant use up to date, and is now in excellent condition. The laundry equipment was made by the Crawford Laundry Machinery Co., of Boston, and consists of 1 brass washer, 1 20-inch extractor, 1 40-inch mangle, 1 2-tier stove, 1 4-gallon copper-

jacketed kettle, 1 Tyler ironer with three irons, 1 set double wash trays, 1 4-compartment dry room. The laundry machinery is operated by a 6-H.P. upright high-pressure engine.

The *Wacouta* is fitted with a Hyde steam-barge brake, galvanized windlass, with two wild cats, two gypsy heads and engine bolted up under deck. Besides the Williamson steam-steering gear, which has chain-and-rod connection to the aft steering tiller, there is a No. 6 Hyde improved Robinson right-and-left-hand screw-steering gear connected direct to the rudder head, which is 4¾ inches diameter.

The machinery was likewise built by the Bath Iron Works. During the past winter it has been overhauled, and the entire propelling plant has been modified and much improved by the Eastern Shipbuilding Co., of New London, Conn. The latter Company have also made extensive alterations in the hull, and the addition of a large pilot house forward has much improved the appearance of this vessel.

The following features in regard to the propelling engines will be of interest:

Cylinders, number	3
H.P., diameter, inches	18
M.P., diameter, inches	28
L.P., diameter, inches	45
Stroke of pistons, inches	30
Valve H.P. (one, piston type), diameter, inches	9
M.P. (one, piston type), diameter, inches	12
L.P.	Double-ported slide valve.
Balance pistons, M. P., diameter, inches	4
L. P., diameter, inches	7
Valve stems, diameter, inches	2
Main steam pipe, diameter, inches	6
Exhaust pipes to M.P. cylinder, diameter, inches	7
L.P. cylinder, diameter, inches	9
condenser, diameter, inches	15
Main steam pipe, area of cross section, square inches	28.27
Exhaust pipes to M.P. cylinder section, square inches	38.48
L.P. cylinder section, square inches	63.62
condenser section, square inches	176.7
Piston rods, diameter, inches	3½
length from top of piston to crosshead, feet and inches,	5- 3
Connecting rods, length from center to center, feet and inches	5-10

Connecting rods, diameter of upper end, inches	4
lower end, inches	5¼
Crank shaft, diameter, inches	9¼
coupling discs, inches	17½
coupling discs, thickness, inches	2¾
journal, diameter, inches	9¼
length, inches	5 at 10, 1 at 12
length of sections Nos. 1 and 3, interchangeable, feet and inches	4–10½
length of section No. 2, interchangeable, feet and inches	5– 7
Crank pins, diameter, inches	9¼
length, inches	9
webs, width, inches	17½
thickness, inches	7¼
Thrust shaft, diameter, inches	9¼
coupling discs, inches	17½
Line shafts, diameter, inches	8¾
coupling discs, inches	17½
Tail shaft, diameter, inches	9¾
Air pump on main engine, diameter, inches	21
stroke, inches	9
Bilge pump on main engine, diameter, inches	4
Distance between cylinder centers H.P. and M.P., feet and inches,	5- 6
H.P. and L.P., feet	5
H.P. cylinder and valve center, feet and inches..	1–10
M.P. cylinder and valve center, feet and inches..	2- 2⅝
L.P. cylinder and valve center, feet and inches..	3- 0½
Length of bedplate, feet and inches	14- 6½
Width of bedplate, feet and inches	7- 9
Crosshead pins, diameter, inches	5
length, inches	8
Front columns, number	3
diameter, inches	4½
Center of shaft above bottom of bedplate, feet and inches	2- 1
cylinder above bottom of bedplate, feet and inches	12- 6
Designed I.H.P.	1,000
revolutions per minute	125
piston speed per minute, feet	625

The M.P. cylinder is placed forward in the vessel, then comes the M.P. piston valve, which takes steam at the ends and exhausts at the center; H.P. piston valve, which takes steam in the center and exhausts at ends; H.P. cylinder, L.P. double-ported slide valve, and L.P. cylinder. None of the cylinders are

jacketed, and the H.P. cylinder only is fitted with a liner. The condenser shell is of cast iron and is at the back of the engine, incorporated into the bedplate and housings.

Length of condenser, feet and inches	14- 6½
Height of condenser, feet and inches	5- 9½
Width of condenser, feet and inches	1- 8⅝
Tubes, number	460
diameter outside, inch	⅝
Cooling surface, square feet	1,129
Ratio of cooling surface to boiler-heating surface	1 to 3.56
Circulating pump	Centrifugal.
Circulating-pump engine	Simple vertical.
fan, diameter, inches	21
width of wheel, inches	6
Diameter of sea-suction circulating pump, inches	6
overboard discharge from condenser, inches	6
Circulating-pump engine cylinder, diameter, inches	5
stroke, inches	6
Feed pump	Blake duplex compound vertical.
Diameter of steam cylinders H.P., inches	6
L.P., inches	10
water cylinders, inches	4½
Length of stroke, inches	10
Diameter of suction, inches	5
discharge, inches	4

Auxiliary feed pump and ash-ejector pump is a duplicate of the main-feed pump.

Feed-water heater. A vertical, cylindrical surface feed-water heater with a cast-iron shell and brass tubes, made by the Wheeler Condenser & Engineering Co., has been installed.

Length over all, feet	7
between heads, feet and inches	4-10
Outside diameter, feet and inches	1- 9½
Steam inlet, diameter, inches	6

All the ship's auxiliaries, with the exception of the steam windlass and the laundry machinery, exhaust into this feed heater.

Worthington horizontal duplex fire pump, fresh-water sanitary pump, salt-water sanitary pump, coil evaporator, Kilbourn ammonia refrigerating machinery with brine circulation, steam-driven Sturtevant ventilating blower, steam-driven assisted-draft

New York and Forbes blower, two General Electric 15-k.w., 80-volt dynamos with Sturtevant engine, steam-steering gear (Williamson engine), laundry machinery and steam Hyde windlass, are also fitted.

The propeller is made of manganese-bronze, built up with three blades.

Diameter, feet and inches	10- 4½
Pitch at 14 inches radius, feet and inches	11- 6
18 inches radius, feet and inches	11- 8½
24 to 60 inches radius, feet	12
ratio	1.157
Diameter of boss, feet and inches	2- 2
Length of boss, feet	2
Thickness of blades at 18 inches radius, inches	3 7/16
42 inches radius, inches	1 3/16
60 inches radius, inch	9/16
Total blade area developed, square feet	24.624
square inches	3,546
projected, square feet	20.653
square inches	2,974
Weight of propeller, pounds	3,750
Disc area, square feet	84.46
Ratio disc area to midship-section area	.267

There are two steel single-ended boilers of the horizontal return fire-tube type, and one vertical donkey fire-tube boiler, all constructed for a working pressure of 160 pounds.

The principal features of the main boilers are:

Length, feet and inches	11- 6 9/16
Diameter, feet and inches	12- 5
Thickness of shell, inch	1
heads top, inch	7/8
bottom, inch	4/8
tube sheets, inch	4/8
furnace, inch	9/16
Combustion chambers, number in each boiler	1
thickness of plates, inch	9/16
Furnaces, diameter, internal, inches	42
external, inches	48
length of grate, feet	6
number in each boiler	3
Tubes, outside diameter, inches	2½

Tubes, length between tube sheets, feet and inches	8– 3
number in each boiler	311
spaced vertically, inches	3¼
horizontally, inches	3⅜
thickness B.W.G., inches	10
Diameter of rivets in shell sheets, inches	1⅛
screw stays, inches	1½
Pitch of screw stays, inches	7
Number of upper through braces	14
Diameter of upper through braces, inches	2½
Heating surface tube, each boiler, square feet	1,732.27
furnaces, each boiler, square feet	151.5
combustion chamber, square feet	124.15
total, each boiler, square feet	2,007.92
Grate surface, each boiler, square feet	60
Calorimeter, each boiler, square feet	8.83
Ratio grate surface to heating surface	1 to 33.46
calorimeter to grate surface	1 to 6.77
Steam space each boiler, cubic feet	255
dome, cubic feet	63.5
Weight of water, each boiler, tons	16.94
Number and diameter of stays around manholes	10 2-inch, and 1 ¾-inch.
Diameter of stays around manholes, inches	2 and 1¾
Width of combustion chamber top, inches	30
water leg at back of boiler, top, inches	7½
bottom, inches	5
Size of manholes, inches	11 by 15
Screw stays at rear of combustion chamber, inches, center	7
Bridge stays at top of combustion chamber, inches, center	7½
Total grate surface main boilers, square feet	120
heating surface main boilers, inches	4,015.84

The donkey boiler has the following dimensions:

Diameter, feet and inches	4– 6
Height, feet	10
Diameter fire box, feet	4
Height fire box, feet and inches	2– 7½
Length of tubes, feet and inches	6– 2½
Width of water leg, inches	2½
Number of tubes	144
Diameter of tubes, inches	2
Thickness of tubes	Standard.
Heating surface, square feet	487.5
Grate surface, square feet	12.5
Ratio grate surface to heating surface	1 to 39

Thickness of shell, inch	$\frac{9}{32}$
heads, inch	$\frac{1}{4}$
furnaces, inch	$\frac{9}{32}$
Diameter of rivets, inch	$\frac{3}{4}$
Screw stays furnace sides, diameter, inches	$1\frac{1}{2}$
pitch, inches	$5\frac{1}{4}$

The main boilers can be forced by means of a New York blower, driven by a single Forbes engine. This fan can deliver to the ash pits 12,500 cubic feet of air per minute.

Diameter of fan wheel, feet	4
Width of fan wheel, feet and inches	2- 1
blades at top, feet and inches	1- $9\frac{1}{2}$
Length of casing, feet and inches	6- 5
Width of casing, feet and inches	2- 5
Height of casing, feet and inches	6- 1
Diameter of inlet, feet and inches	2-10
Width of discharge, feet and inches	2- $3\frac{1}{2}$
Length of discharge, feet and inches	2- $2\frac{1}{2}$
Area of inlet, square inches	908
discharge, square inches	729
Diameter of steam cylinder, inches	6
Length of stroke, inches	5
Diameter of blower shaft, inches	$1\frac{1}{16}$
fly wheel, inches	20
Over-all length of fan and engine, feet and inches	5- 3

The ventilating fan has a suction leading from the principal living spaces, and this air can be discharged into the fire room, engine room or atmosphere at will.

A 4-inch Davidson ash ejector has been fitted, the auxiliary feed pump and the fire pump being connected to the same. The vessel is fitted throughout with steam heat, an excellent constant-pressure plumbing and sanitary system, Hermes' soil ejectors (no pump under water closets), hot and cold fresh and salt water throughout, searchlight, galvanized stockless anchors and cables, pipe berths for crew, fire main with hose connections, deck-hand pumps, call bell and signal service, large store space, commodious cold-storage rooms, divided for meat, fish and fowl, brine-circulation and ice-making tanks, and an excellent complete equipment.

MACHINERY TESTS, MAY 3, 1902.

Course: Eastern extremity Long Island Sound, off New London Harbor.

Atmospherical conditions: Tranquil, very still, slight mist, damp, no wind.

Sea conditions: Calm.

Draught forward, 10 feet 9 inches.

Draught aft, 14 feet 1 inch.

Draught, mean, 12 feet 5 inches.

Displacement, 1,000 tons.

Object of trials: To adjust machinery, test all new apparatus installed, and give propelling machinery a thorough, complete trial under various conditions.

TEST NO. 1.

Run commenced	10·13 A.M.
finished	10·50 A.M.
Period of time	37 minutes.
Total number of engine revolutions	1,790
Average revolutions per minute	48.4
Maximum revolutions per minute	51
Minimum revolutions per minute	47.5
Vacuum, inches	26
Steam pressure at boilers, pounds	155
engines, pounds	154
Maximum steam pressure, boilers, pounds	155.5
Steam pressure M.P. receiver, pounds	0
L.P. receiver, inches of vacuum	13.1
Circulating pump, revolutions	180
Feed pump, double strokes	14.6
Temperature of hotwell, degrees Fahrenheit	61
overboard discharge, degrees Fahrenheit	67
sea water, degrees Fahrenheit	48
feed water, degrees Fahrenheit	178
engine room, degrees Fahrenheit	80
fire room, degrees Fahrenheit	99
Ventilating blower, revolutions	400
Fresh-water sanitary pump, double strokes	10
Salt-water sanitary pump, double strokes	11.5
Dynamo No. 1, revolutions	419.5
steam	104.5
voltage	80
ampères	42

Main steam line throttled. Ice machinery, evaporator, No. 2 dynamo and forced-draft blowers not running. Soil ejector and steering gear in operation, also No. 1 dynamo, ventilating blower and fresh and salt-water sanitary pumps.

POWER-INDICATOR CARDS.

	Record 1.	Record 2.	Record 3.
Revolutions per minute	51	48	47.5
I.H.P. of high-pressure cylinder	38.63	35.8	34.3
intermediate-pressure cylinder	32.16	26.6	25.1
low-pressure cylinder	22.36	17.81	16.1
M.E.P. of high-pressure cylinder	19.65	19.35	18.75
intermediate-pressure cylinder	6.76	5.94	5.67
low-pressure cylinder	1.82	1.54	1.41
M.E.P. referred to L.P. cylinder	7.77	7.10	6.75
Total I.H.P.	93.15	80.21	75.5

Average I.H.P. for entire run, 82.95. Speed, 4.54 knots per hour.

TEST NO. 2.

Run commenced	11'05 A. M.
finished	11'35 A. M.
Period of time	30 minutes.
Total number of engine revolutions	2,285
Average revolutions per minute	76.16
Maximum revolutions per minute	77
Minimum revolutions per minute	75.5
Vacuum, inches	27½
Steam pressure at boilers, pounds	155
engines, pounds	154
Maximum steam pressure at boilers, pounds	155.5
Steam pressure M.P. receiver, pounds	8
L.P. receiver, inches of vacuum	11.5
Circulating pump, revolutions	202
Feed pump, double strokes	18.4
Temperature of hotwell, degrees Fahrenheit	62.5
overboard discharge, degrees Fahrenheit	75
sea water, degrees Fahrenheit	48.5
feed water, degrees Fahrenheit	165
engine room, degrees Fahrenheit	80
fire room, degrees Fahrenheit	98

Blower engine, sanitary pump, dynamo and all other auxiliaries as per Test No. 1.

POWER-INDICATOR CARDS.

	Record 1.	Record 2.	Record 3.
Revolutions per minute	76	77	75.5
I.H.P. of H.P. cylinder	109	110.8	113
M.P. cylinder	81.19	88.14	90.6
L.P. cylinder	51.29	49	48.5
M.E.P. of H.P. cylinder	37.22	37.3	38.9
M.P. cylinder	11.45	12.27	12.88
L.P. cylinder	2.8	2.64	2.67
referred to L.P. cylinder	13.5	13.64	14.22
Total I.H.P.	241.48	247.94	252.1

Average I.H.P. for entire run, 247.2; speed, 7.1 knots per hour.

TEST NO. 3.

Run commenced	11·45 A.M.
finished	12·15 P.M.
Period of time	30 minutes.
Total number of revolutions	3,103
Average revolutions per minute	103.14
Maximum revolutions per minute	103.5
Minimum revolutions per minute	103
Vacuum, inches	26½
Steam pressure at boilers, pounds	154
engines, pounds	151.5
Maximum steam pressure at boilers, pounds	155
Steam pressure M.P. receiver, pounds	26.5
L.P. receiver, inches vacuum	1.85
Circulating pump revolutions	220
Feed pump, double strokes	18
Temperature of hotwell, degrees Fahrenheit	111.5
overboard discharge, degrees Fahrenheit	91
sea water, degrees Fahrenheit	48.5
feed water, degrees Fahrenheit	154
engine room, degrees Fahrenheit	79.5
fire room, degrees Fahrenheit	98.5

Blower engine, sanitary pump, dynamos and all other auxiliaries as per Test No. 1.

POWER-INDICATOR CARDS.

	Record 1.	Record 2.	Record 3.
Revolutions per minute	103	103.5	103.3
I.H.P. of H.P. cylinder	218	228	231
M.P. cylinder	215	214	212
L.P. cylinder	134	143.5	143
M.E.P. of H.P. cylinder	55.06	57.1	58.2
M.P. cylinder	22.41	22.17	21.96
L.P. cylinder	5.4	5.73	5.70
referred to L.P. cylinder	23.49	24.01	24.09
Total I.H.P.	567	585.5	586

Average I.H.P. for entire run, 579.5; speed for 30 minutes by log, 9.92 knots per hour.

TEST NO. 4.

Run commenced	1·30 P.M.
finished	2·00 P.M.
Period of time	30 minutes.
Total number of revolutions	3,605
Average revolutions per minute	120.16
Maximum revolutions per minute	121
Minimum revolutions per minute	119
Vacuum, inches	26½
Steam pressure at boilers, pounds	148
engines, pounds	143.7
Maximum steam pressure at boilers	151
Steam pressure M.P receiver, pounds	41.75
L.P. receiver, inches vacuum	2.75
Circulating pump revolutions	360
Feed pump, double strokes	23
Temperature of hotwell, degrees Fahrenheit	117
overboard discharge, degrees Fahrenheit	88
sea water, degrees Fahrenheit	48
feed water, degrees Fahrenheit	142
engine room, degrees Fahrenheit	80
fire room, degrees Fahrenheit	97

Blower engine, sanitary pump, dynamos and all other auxiliaries as per Test No. 1.

POWER-INDICATOR CARDS.

	Record 1.	Record 2.	Record 3.
Revolutions per minute	120	121	119
I.H.P. of H.P. cylinder	318	321	318
M.P. cylinder	337	373	338
L.P. cylinder	252	257	261
M.E.P. of H.P. cylinder	68.8	69	69.4
M.P. cylinder	30.1	33.1	30.5
L.P. cylinder	8.78	8.83	9.1
referred to L.P. cylinder	32.24	33.58	32.8
Total I.H.P.	907	951	917

Average I.H.P. for entire run, 925 ; speed, 11.92 knots per hour.

TEST NO. 5.

Run commenced	2·30 P. M.
finished	3·30 P. M.
Period of time	60 minutes.
Total number of revolutions	7,545
Average number of revolutions	125.66
Revolutions for first 15 minutes	1,760
Average revolutions for first 15 minutes	117.33
Revolutions for second 15 minutes	1,935
Average revolutions for second 15 minutes	129
Revolutions for third 15 minutes	1,860
Average revolutions for third 15 minutes	124
Revolutions for fourth 15 minutes	1,990
Average revolutions for fourth 15 minutes	132.67
Maximum revolutions per minute	134
Minimum revolutions per minute	115

Vacuum, inches	26.4
Steam pressure at boilers, pounds	153
engines, pounds	151
Maximum steam pressure at boilers, pounds	155.5
Steam pressure M.P. receiver, pounds	45
with by-pass opened, pounds	64
L.P. receiver, pounds	3.4
L.P. receiver, with by-pass opened, pounds	8.2
Circulating pump, revolutions	400
Maximum circulating pump, revolutions	410
Minimum circulating pump, revolutions	390
Feed pump, double strokes	25
Temperature of hotwell, degrees Fahrenheit	122
overboard discharge, degrees Fahrenheit	96
sea water, degrees Fahrenheit	48
feed water, degrees Fahrenheit	130
engine room, degrees Fahrenheit	83
fire room, degrees Fahrenheit	110
Forced draft blower, maximum revolutions	420
average revolutions	300

Blower engine, sanitary pumps, dynamos, and all other auxiliaries as per test No. 1.

POWER–INDICATOR CARDS.

	Rec. 1.	Rec. 2.	Rec. 3.	Rec. 4.	Rec. 5.	Rec. 6.
Revolutions per minute	121	125	125	132	131	129.5
I.H.P. of H.P. cylinder	345	357	361	210	222	309
M.P. cylinder	374	389	387	563	542	453
L.P. cylinder	266	290	286	448	405	358
M.E.P. of H.P. cylinder	73.8	74.2	75	41.25	44.1	62
M.P. cylinder	33.2	33.35	33.2	45.7	44.52	37.5
L.P. cylinder	9.12	9.62	9.48	14.08	12.83	11.48
referred to L.P. cyl	34.66	35.30	35.2	39.58	38.32	36.9
Total I.H.P.	985	1036	1034	1221	1169	1120

Average I.H.P. for entire run, 1,100; maximum I.H.P. for entire run, 1,250; average speed, 12.9 knots per hour; maximum speed, 13.7 knots per hour.

TEST NO. 6.

Run commenced	4·08 P. M.
finished	4·50 P. M.
Period of time	42 minutes.
Total number of revolutions	5,345
Average number of revolutions	127.26
Maximum revolutions per minute	133
Minimum revolutions per minute	117
Vacuum, inches	26½
Steam pressure at boilers, pounds	155 to 142

Steam pressure at engines, maximum, pounds	153
minimum, pounds	140
average, pounds	148
M.P. receiver, maximum, pounds	65
minimum, pounds	43
average, pounds	57
L.P. receiver, maximum, pounds	9.5
minimum, pounds	6.1
average, pounds	8.25
Circulating pump, revolutions	400
Maximum circulating pump, revolutions	420
Minimum circulating pump, revolutions	380
Feed pump, double strokes	28.5
Temperature of hotwell, degrees Fahrenheit..... 112 to 136; average,	125
overboard discharge, degrees F... 80 to 98; average,	86
sea water, degrees Fahrenheit	48.5
feed water, degrees Fahrenheit	200
engine room, degrees Fahrenheit	84.5 to 87
fire room, degrees Fahrenheit	98 to 108
Forced draft blower, maximum revolutions	450
average revolutions	300

All auxiliaries, except evaporator, in operation.

POWER-INDICATOR CARDS.

	Record 1.	Record 2.
Revolutions per minute	131.5	130.5
I.H.P. of H.P. cylinder	276	243
M.P. cylinder	530	507
L.P. cylinder	431	423
M.E.P. of H.P. cylinder	54.3	48.3
M.P. cylinder	43.2	41.64
L.P. cylinder	13.6	13.46
referred to L.P. cylinder	40.17	38.4
Total I.H.P.	1,237	1,173

Maximum I.H.P., 1,260; average I.H.P., 1,150; maximum speed, 13.75 knots per hour; average speed, 13.15 knots per hour.

On builders' official speed and power test over the measured mile, October, 1894, the *Wacouta* attained a spurt speed of 12.64 knots with 130.3 revolutions and 1,070 I.H.P., 155 pounds of steam. She was designed to give 1,000 I.H.P. with 125 revolutions and 165 pounds of steam. On this trial, after adjusting machinery, the Eastern Shipbuilding Co. obtained for 15 minutes a mean engine speed of 132.67 revolutions, with a maximum of 134. The maximum I.H.P. was 1,260; the maximum speed being 13.75 knots.

	Revs.	I.H.P.	Speed.
			knots.
Designed	125	1,000	12
Official trial, October, 1894	130.3	1,070	12.64
Eastern Shipbuilding Co. trial, May, 1902	134	1,260	13.75

Appended is a table giving in a complete manner the results of the steam trials before described.

Speed, knots per hour.	Revolutions per minute.	Piston speed, feet per minute.	Advance per revolution, feet.	Revolutions to go one knot.	Slip, per cent.	I.H.P.	M.E.P. referred to L.P. cylinder.	Indicated thrust, pounds.
4	44	220	9.212	660	23.1	63	5.95	3,937
5	54.7	273.5	9.261	656.5	22.8	107.5	8.17	5,404
6	65.2	326	9.325	652	22.3	166.5	10.62	7,022
7	75.3	376.5	9.419	645.5	21.6	240	13.25	8,765
8	85.2	426	9.514	639	20.8	332	16.21	10,716
9	94.9	474.5	9.626	631.6	19.9	449	19.68	13,011
10	104	520	9.743	624	18.75	590	23.6	15,601
11	112.5	562.5	9.907	613.7	17.43	755	27.92	18,455
12	120.6	603	10.083	602.9	15.96	932	32.14	21,252
13	128.5	642.5	10.251	593.1	14.54	1,120	36.25	23,969
14	135.8	679	10.446	582	12.95	1,315	40.28	26,629

Speed, knots per hour.	I.H.P. per 100 sq. ft. wetted surface.	Admiralty coefficient displacement, $\frac{D^{\frac{2}{3}} \times V^3}{\text{I.H.P.}}$.	Admiralty coefficient mid. sec., $\frac{A \times V^3}{\text{I.H.P.}}$.	Frictional resistance, pounds.	E.H.P. friction.	Wave-making and eddy resistance, pounds.	Estimated E.H.P. wave making eddy, etc.	Total resistance in pounds.
4	.81	110.7	321	989	12.2	266	3.2	1,255
5	1.37	126.4	367.4	1,487	22.8	339	5.2	1,826
6	2.12	141	410	2,076	38.3	453	8.3	2,529
7	3.07	155.3	451.6	2,753	59.2	565	12.2	3,318
8	4.24	167.6	487.3	3,514	86.3	985	24.2	4,499
9	5.74	176.5	513.1	4,360	120.8	1,611	44.7	5,971
10	7.54	184.2	535.6	5,287	162.5	2,508	77	7,795
11	9.65	191.6	557.1	6,294	212.7	3,985	134.6	10,279
12	11.92	201.5	585.9	7,381	272	5,417	199.6	12,798
13	14.32	213.2	619.9	8,545	341.3	7,005	278.7	15,550
14	16.81	226.8	659.4	9,786	420.9	8,265	355	18,051

Speed, knots per hour.	Total E.H.P.	Estimated propulsive coefficient.	$\frac{\text{I.H.P.} \times 33{,}000}{\text{Speed ft. per min.}}$	I.T. per square in. developed blade area.	I.T. per square in. projected blade area.	E.T. per square in. developed blade area.	E.T. per square in. projected blade area.	$\frac{R^3}{\text{I.H.P.} \times 100}$.
4	15.4	.245	5,129	1.11	1.32	.35	.42	13.53
5	28	.26	7,001	1.52	1.81	.52	.61	15.23
6	46.6	.28	9,037	1.98	2.36	.72	.85	16.65
7	71.4	.30	11,166	2.47	2.95	.94	1.12	17.79
8	110.5	.335	13,514	3.02	3.60	1.27	1.51	18.63
9	165.5	.37	16,246	3.67	4.37	1.68	2	19.03
10	239.5	.41	19,214	4.39	5.24	2.19	2.61	19.05
11	347.3	.46	22,353	5.20	6.20	2.89	3.43	18.86
12	471.6	.51	25,292	5.99	7.14	3.61	4.27	18.82
13	620	.56	28,057	6.76	8.06	4.36	5.22	18.95
14	775.8	.59	30,590	7.51	8.96	5.07	6.07	19.05

DESCRIPTION AND TRIALS OF U. S. MONITOR *ARKANSAS.*

By Lieutenant C. K. Mallory, U. S. Navy.

This vessel is a single-turret harbor-defense monitor built by the Newport News Shipbuilding and Dry Dock Co., and delivered to the Government at the Navy Yard, Norfolk, Virginia, the 6th of September, 1902. The plans were furnished by the Navy Department and the details worked out by the contractors. The contract was signed the 11th of October, 1898; price, $860,000; time for delivery, twenty-seven months. Boats, anchors, chains, armor and ordnance were not included in this price. The speed was twelve knots per hour for two hours with not over one inch water pressure of air in the fire rooms. The 13th of December, 1898, this speed was reduced to eleven and one-half knots because of the lengthening of the hull twenty-seven feet. The time allowance was extended two months and cost $960,000. The time has at intervals been extended to cover to date of delivery.

There was no premium for excess of speed, but $5,000 penalty per quarter knot for two quarters and $10,000 for each of the next two quarters' deficiency in speed.

The weight of the machinery was limited to 240 tons, with a penalty of $500 per ton in excess to five per cent., and beyond this $10,000.

The hull is constructed of mild steel with transverse frames three feet apart, special frames being worked in where necessary. The stem and stern posts are cast steel. The flat keel plates are in two thicknesses; outer, 25 pounds; inner, 20 pounds. The vertical keel is 30 inches deep of 20-pound plate. The side plating is 20 pounds and the ram plates are 30 pounds. The

armor sits on a shelf, and is 8 inches thick at midships and tapers to 4 inches thick forward and aft at waterline.

Length of hull between perpendiculars, feet	252
on L.W.L., feet	252
Beam, extreme, and at L.W.L., feet	50
Ratio of length to beam at L.W.L.	5.04
Depth, molded (top of main deck beams at side to bottom of frame), feet and inches	14-10½
Displacement at normal draught, tons	3,233
per inch at L.W.L.	25.40
Draught, normal, forward, 12 feet 5⅛ inches; aft, 12 feet 9 inches; mean, feet and inches	12- 7 3/16
Area immersed midship section, square feet	600
L.W.L. plane, square feet	10,656
Center of gravity forward of midship section, feet and inches	1- 5⅞
above base line, feet	12.85
of L.W.L. plane, aft from mid. sec., ft. and ins.	5- 6
Center of buoyancy, forward from midship section, ft. and ins.	1- 5⅞
above bottom of keel, feet and inches	6-10 3/16
Transverse metacenter above the center of buoyancy, feet and inches	4-11 3/16
Longitudinal metacenter above the center of buoyancy, feet and inches	1,558- 1 1/16
Coefficient of fineness, block	.718
of L.W.L.	.846
of midship section	.960
Number of watertight compartments	132
Height of truck light above the L.W.L., feet and inches	78- 7¼
floor of military top above the L.W.L., feet and inches	34- 4⅝
Number of frames	85

BATTERY.

This consists of two 12-inch B.L.R. in a balanced turret forward, with angle of train 150 degrees each side; four 4-inch R.F.R. at corners of superstructure, three 6-pounder semi-automatic, four 1-pounder Maxim-Nordenfeldt, one 1-pounder R.F.G., two 6-mm. Colt's automatic.

BOATS.

One 28-foot steam cutter, one 28-foot launch, one 28-foot whaleboat, one 28-foot gig whaleboat, two 26-foot cutters, one 18-foot dinghy.

COAL BUNKER CAPACITIES.

Compartment.	Cubic feet.	Tons.	Compartment.	Cubic feet.	Tons.
A 17	490	11.4	A 18	490	11.4
A 21	3,445.5	80.1	A 21	3,445.5	80.1
B 3	1,082	25.6	B 2	1,082	25.16
B 5	993	23.09	B 4	993	23.09
B 7	578	13.44	B 6	948	22.05
C 3	617	14.35	B 2	617	14.35
	7,205.5	167.98		7,575.5	176.15
	7,575.5	176.15			
Totals	14,781	334.13			

TANK CAPACITIES.

Compartment.	Trimming tanks, gallons.	Tons salt water.	Tons fresh water.
A 1	3,721	14.21	13.82
A 2	1,506	5.59	5.44
A 3	4,629	17.19	16.71
D 6	3,611	13.79	13.41

Double bottoms, for reserve feed, B 84, 85, 88, 89, 90, 91, 94, 95, each will contain 1,895.73 gallons of fresh water, or 15,165.84 gallons.

DRAINAGE SYSTEM.

A 10-inch main drain pipe runs from the after end of the boiler compartment to the forward end of the engine compartment, and is fitted with a valve that may be worked from the deck. In the engine compartment the main drain divides into two 8-inch branches leading to the main circulating pumps, which are also provided with direct suctions to the engine bilge. A 4-inch suction leads from the main drain aft to the fire-and-bilge pumps in the engine room. Three-inch branches, which connect to both main and auxiliary drains, lead to the auxiliary feed pumps on either side. The main drain may be charged from the sea or from the main injections.

A 4-inch auxiliary drain extends from the forward manifolds in compartments A 66 and A 67 aft to the manifolds in the engine room. The double bottoms are drained through pipes connecting with these manifolds. The following pumps can be

used on the auxiliary drain pipe, main circulating pumps, auxiliary feed pumps, fire-and-bilge pumps and two hand pumps on deck. The engine-room pumps may also be used on bilges of engine rooms direct. The main bilge pumps are worked by eccentrics on main engine shafts and drain crank pits and engine bilges direct.

The Fire Pipes.—A 4-inch main on each side and under the main deck runs fore-and-aft with frequent risers. There are thirty-one fire plugs. The relief valve is set at 90 pounds. The connecting pumps are the fire-and-bilge, the auxiliary feeds and the hand pumps on the main deck.

Salt-water System.—The salt-water main is supplied by the water-service pump in the engine room or the hand pump on main deck. It leads to water closets, bath rooms and wash rooms.

Fresh-water System.—The distillers may discharge into the fire-room tank, main supply tanks and the forward trimming tank. The main supply tanks may be filled from the distillers, from the dock or water boats through a 2½-inch connection on main deck. The water is pumped from the main supply tanks through a 5-inch hand pump to the distributing tank on the superstructure. From this upper tank the distributing main leads and feeds by gravity. A 105-gallons tank in the fire room is filled from the distiller direct. A 21-gallons tank in the firemen's washroom is filled from the main. A small tank for the sick bay and one for the air compressor are filled from the main.

Waste-water Drains.—The captain's and sick-bay baths and the firemen's wash room drain into waste tanks below decks, which are pumped out by small steam pump in engine room. All are connected to the flushing main. The pantries drain into the scuppers.

VENTILATING SYSTEM.

There are eight ventilating systems, and these are supplied by eleven fans, two being steam, the others electric.

The Forward System.—Two fans in the dynamo room receive their air supply from ventilators in the hammock nettings and discharge through ducts leading forward on either side of the

turret to all compartments forward of and including the dynamo room. These are 70-inch fans; diameter of blades, 42 inches; width at tips, 9 inches, and they are rated to give 4,500 cubic feet of air at 450 revolutions. The motors are rated at 3½ H.P at 470 revolutions. The air escapes from these compartments through the riding bits and hatches when open. When these are closed it passes aft to the firemen's washroom, and is exhausted by the Monogram fans therein and passes up through the mast. This No. 5 Monogram fan is the Sturtevant standard, with 32½ inches of wheel diameter and 5 inches width at tip. The motor is rated at 1½ H.P. at 1,220 revolutions, and gives 1,460 cubic feet per minute at a pressure of 1½ ounces.

After System.—Two No. 5 Monogram fans, one in each shaft alley, take their air supply from the hammock berthings on superstructure deck and deliver into all compartments on berth deck abaft the engine room. The air escapes through cowls fitted on the deck above, or, when these are closed, through the armored hatch to the space under the superstructure deck.

Steering-Engine Room System.—A duct leading from a cowl on the hammock berthing conveys the air, and it is exhausted by a Monogram No. 5 blower and delivered into the engine room.

The Main-Deck System.—A 70-inch fan on the main deck at starboard side of smoke-pipe casing receives its supply from a duct having branches from all the compartments on this deck and discharges the air into a ventilator having a cowl above the bridge-deck awning. One No. 5 Monogram fan under the superstructure deck draws from the shower baths, water closets, and discharges through a ventilator above the hammock berthing.

Engine-Room System.—Two 70-inch fans in the passage forward of the engine room take air down the after part of the armored ventilator and deliver it into the engine room, the wing passages and the magazine air spaces. The air of the wing passages goes into the berth-deck compartments at both ends.

The Coal-Bunker System.—The gravity system is used; the supply pipes leading from the upper deck below the hammock berthings, and the exhaust to the space about the smoke pipe, mast and engine hatch.

Fire-Room Forced Draft.—Two steam fans in the after part of the boiler compartment and above the evaporators draw air down the forward part of the armored ventilator and deliver it at the peripheries into the compartment.

Magazine Air Spaces.—The air space around the forward magazines is supplied by the fans in the dynamo room and escapes through pipe to mast. For the after magazine space the supply is from the engine-room fans, and the escape is into the engine room at the top of the casing or space.

THE ELECTRICAL PLANT.

The dynamo room is on the berth deck abaft the turret and forward of the firemen's wash room. It extends athwartships, and the forward ends of wing passages open into it, and the passages on each side of turret base extend from it to berth-deck crew space forward. It is well ventilated. In it are the four dynamos, the two ventilating fans for the forward system, the main switch board, the searchlight switchboard, the air compressor. The dynamos are 32-kilowatts at 400 revolutions per minute. The engines are tandem-compound, single-crank, and use steam of 100 pounds pressure. They are directly connected to the dynamo. The diameters of the cylinders are 9 and 15 inches, and the stroke, 6 inches. The voltage is 80.

The engines and dynamos were furnished by the General Electric Co., of Schenectady, N. Y. There are six ventilator motors, No. 5 Monogram, of 1½ H.P. each; five steel-plate fans of 42 inches of 3½ H.P. each; two turret-turning motors of 35 H.P. each; two 4-inch ammunition hoists of 3¾ H.P. each; one 3 and 6-pounder ammunition hoist of 3¾ H.P.; two 12-inch ammunition hoists of 20 H.P. each; two 12-inch elevating motors of 3½ H.P. each; and two 12-inch ramming motors of 5 H.P. each. There are two searchlights using 50 volts and 70 ampères; eight 5-candlepower incandescent lamps, two hundred and forty-nine 16-candlepower; ten 32-candlepower with a total of 4,344 candlepower.

The dimensions of the sets are 88¼ inches long, 54 inches wide, 74⅛ inches high.

The requirements are: Steam, 100 pounds, 80 volts, 400 ampères and 400 revolutions.

The trial of the sets showed as follows: Steam, 100 pounds; vacuum, 21; revolutions, 405; voltage, 82.4; ampères, 404; kilowatts, 33.29; temperature of armature, 48.5 degrees; of core tips, 50; of air, 34; water per kilowatt per hour, 40.7 pounds; water per H.P. per hour, 24.3 pounds; efficiency of dynamo, 89 per cent.; of engine, 90 per cent.; of set, 80 per cent.; weight of set, each, 9,666 pounds.

ENGINES.

The Steering Engine.—It was manufactured by Williamson Bros. Co., of Philadelphia, Pa. It is placed in the after berth-deck compartment under the protective deck, and is a two-cylinder, simple-expansion, horizontal, direct-acting engine, working, through worm-and-screw-gear, the tiller. It uses a steam pressure of 90 pounds, and the diameter of cylinders is 8 inches and the stroke 7 inches. On the preliminary official trial the helm was put from amidships to hard-a-starboard in 13 seconds.

Anchor Engine.—This is placed in a small steel deck house on the forward main deck and just forward of the turret. It was manufactured by the Hyde Windlass Co., of Bath, Maine. It uses a steam pressure of 90 pounds, and the diameter of the cylinders is 9 inches, and the stroke 9 inches. The engine, upon the preliminary official trial trip, took in both anchors, weighing 5,480 pounds, starboard, and 5,130 pounds, port, with 114 fathoms of chain out, at the rate of six fathoms per minute.

Main Engines.—These are three-cylinder, triple-expansion, direct-acting. They are placed abreast and in one water-tight compartment. The framing is of cast-iron columns at the back, which extend down to seatings upon the condenser, and wrought-steel columns at the front. The high-pressure cylinder is forward, and the low-pressure aft. The cylinders are tied together by side rods on each side, and the two engines are connected by athwartship rods, one between the high-pressure cylinders and one between the low-pressure cylinders.

The cylinders are of cast iron, the pistons of cast steel. The high pressure and intermediate use piston valves, and the low

pressure a double-ported slide valve. The Stephenson side-bar link is used and connects directly to the valve stems.

The bed plates are cast steel and in two sections for each engine.

All the cylinders are steam jacketed.

ENGINE DATA.

Cylinders, diameter, H.P., inches	17
I.P., inches	26½
L.P., inches	40
stroke, inches	24
Valves, diameter, H.P., inches	9
I.P. (2), inches	9
L.P., long, inches	25½
wide, inches	44
Balance piston, diameter L.P. (only), inches	7½
Valve stems, diameter, H.P., inches	2
I.P., inches	2
L.P., inches	2½
Steam pipes, main (2), diameter, inches	5½
1st receiver, diameter, inches	7
2d receiver, diameter, inches	10
Main exhaust, diameter, inches	13
Volume swept by H.P. piston per stroke, cubic feet	3.15
I.P. piston per stroke, cubic feet	7.52
L.P. piston per stroke, cubic feet	17.45
Piston rods, diameter, inches	3½
of hole, inches	1½
length from piston to crosshead, inches	39
Connecting rods, length, inches	48
diameter, upper end, inches	3½
lower end, inches	4½
hole, inches	2
crosshead bolts (2), diameter, inches	1½
crank-pin bolts (2), diameter, inches	2
Crosshead, ahead surface, square inches	131
backing, square inches	106
pins, diameter, inches	4½
length, inches	8½
Reversing gears, steam cylinder, diameter, inches	8
stroke, inches	8
oil cylinder, diameter, inches	4
Shafts	Nickel-steel, bored.
Crank shafts, diameter, inches	7½

Crank shafts, hole, diameter, inches	4¾
length, each section, after, feet	5
forward, feet and inches	7–11½
bearings, diameter, inches	7½
length, inches	9
pins, diameter, inches	8
length, inches	9½
Thrust shafts, diameter, inches	7½
hole, diameter, inches	4½
length, feet and inches	9–10½
collars, number	11
diameter, inches	11½
width, inch	1
Propeller shaft, diameter, inches	7½
hole, diameter, inches	4½
length, feet and inches	44– 1
stern tube, length, inches	21
of lignum vitae bearings, inches	30
bearing, length	30½
Solid-forged couplings, diameter, inches	14½
thickness, inches	2
coupling bolts, number	6
diameter taper, inches	1½ to 2

Clearance of cylinders in per cent. of stroke displacement:

Starboard, top	H.P., 22.47; I.P., 14.23; L.P.,	9.73
bottom	H.P., 24.52; I.P., 21.78; L.P.,	16.77
Port, top	H.P., 22.47; I.P., 14.76; L.P.,	9.19
bottom	H.P., 24.52; I.P., 22.09; L.P.,	16.61

Main Condenser.—There is one condenser for each engine, and it is of cast iron and supports the outboard framing of the engine. It is clothed with asbestos and galvanized iron. The tubes are horizontal, and extend fore-and-aft. The tubes are the regular Navy standard, Muntz metal, seamless-drawn, No. 18 B.W.G., ⅝-inch in diameter.

Number of tubes in each condenser	905
Length of tubes, feet and inches	10–9½
Surface of tubes, square feet	1,600

Main Air Pumps.—The air pump is attached to the main condenser at the after end outboard, and is actuated through twin levers from the low-pressure crosshead. It is vertical, single-acting.

Diameter of air pump, inches	16½
Stroke of air pump, inches	8½
Diameter of plunger rod, inches	2½
Number of foot valves	6
Area through foot valves, square inches	59
Number of bucket valves	6
Area through bucket valves, square inches	59
Number of delivery valves	6
Area through delivery valves, square inches	59
Ratio of volumes per stroke of air pump to L. P. piston	16.6

Main Circulating Pumps.—There is one for each engine, placed in the after outboard corners of the engine room. They are two-cylinder, direct-acting, vertical, centrifugal. They may draw from sea or bilge and deliver through the condenser or overboard. The casings are of composition.

Engine, diameter, inches	5
Stroke, inches	6
Wheel, diameter, feet and inches	2–6
Width at tip, inches	1½
Pipes, inlet, diameter, inches	8
(double at wheel), outlet, diameter, inches	8
Discharge per minute from bilge, gallons	3,200

Auxiliary Condenser.—There is one, placed in the center of the engine room between the main engines and under the ladder from the deck. It was manufactured by M. T. Davidson, of New York, N. Y.

Length over all, feet and inches	8–10 1/16
Height, inches	46½
Width, inches	28½
Cooling surface, square inches	450
Diameter of pumps, steam, inches	6
air, inches	10
circulating, inches	10
Stroke, inches	10
Number of tubes	351
Diameter of tubes, inch	⅝
Length of tubes, feet and inches	7–10

Screw Propellers.—The two screws are modified Griffiths, of manganese-bronze, right-handed on starboard and left-handed on port side. They are three-bladed, adjustable pitch. The hubs are spherical, cut off at ends.

Diameter, feet	9
Variable pitch, feet and inches	6-3 to 8- 3
Hub, diameter, inches	24¾
Helicoidal area of each, square feet	25.6
Projected area, square feet	22.6
Length of hub, inches	18¾
Taper of shaft in hub, inches	1 in 17

BOILERS.

There are four boilers of the Thornycroft type, Daring pattern. They are placed in one watertight compartment, with the fire room running athwartships. Each boiler has one steam drum, three water drums and two furnaces. Each furnace has two doors. The boilers were originally built with air heaters, but the first steam trial resulted unfortunately, in causing a very high and dangerous temperature in the protective deck immediately above, and the air heaters were removed. The boilers were designed to carry a working steam pressure of 250 pounds.

The drums and tubes are of mild steel; the heads of the drums are welded on to the shells; the tubes are seamless, cold drawn. There is a feed-regulator float in the steam drum.

Outside dimensions of boilers:	
Height, feet and inches	10- 9
Width, feet and inches	14- 1
Length, fore-and-aft, feet and inches	8-10
Drums, steam, length, feet	9
inside diameter, inches	36
thickness, inch	1⅛
water, length, center, feet and inches	7- 3
inside diameter, inches	19
thickness, inch	⅝
wing, length, feet and inches	8- 5½
inside diameter, inches	19
thickness, inch	⅝
Tubes, steam, outside diameter, inches	1¼
thickness	No. 11 B.W.G.
number	1,104
water wall, outside diameter, inches	1¼
thickness	No. 10 B.W.G.
number	228
Grates, length, feet and inches	5- 7½
width, feet and inches	4- 5

Outside dimensions of boilers:

Downcomers, (8 for center drum), diameter, outside, inches...	4
(1 for each wing drum), diameter, inches.....	6
thickness, inch.....	¼
Smoke pipe, inside diameter, feet and inches.....	6- 3
height above the grates, feet and inches.....	70- 6
Furnace doors, width, inches.....	18
height, inches.....	15
Deadplate above the fire-room floor, feet and inches.....	1- 7

Main and Auxiliary Feed Pumps.—There are two main and two auxiliary feed pumps, all of the same pattern and size—8 inches steam cylinder, 5 inches water cylinder, and a stroke of 12 inches. They were made by the M. T. Davidson Company, of New York. They are placed in the forward outboard corners of the boiler compartment.

Fire-and-Bilge Pump.—There is one pump, placed in the engine room; it is a 7-inch by 7-inch by 12-inch pump, manufactured by M. T. Davidson & Co., of New York.

Water-service Pump.—There is one pump, placed in the engine room; a 7-inch by 7-inch by 12-inch Davidson. It draws only from the sea and delivers into the engine water-service pipes, the fire main and the distiller circulating pipe.

Hotwell Pumps.—There are two pumps, placed in the engine room; they are 6 inches by 6 inches by 8 inches. They are manufactured by M. T. Davidson & Co., of New York. They have suctions from the air-pump channelways, from the trap of the feed-water heater, from the side of the ship above the water line, for taking in fresh water, and ash hoist from the reserve feed tanks.

Ash Hoist.—There is one Williamson's reversible engine, placed in the smoke-pipe room and on a level with the superstructure deck. The two cylinders are 4½-inch diameter and 4½-inch stroke. It will hoist 300 pounds from the fire room to the deck in five seconds, using steam of 80 pounds pressure.

Weights of moving parts:

Pistons H.P. (1), pounds.....	152.5
I.P. (1), pounds.....	276
L.P. (1), pounds.....	559

Piston rods (3), pounds	929
Connecting rods (3), pounds	1,716
Crossheads, complete (3), pounds	305
Crankpin brasses (1 engine), pounds	305
Engines complete, pounds	103,242
Boilers complete, empty, pounds	170,137
to steaming level, pounds	188,937
All machinery in engine and boiler compartments	565,647

Deck Winches.—The two winches were manufactured by the Hyde Windlass Co., of Bath, Maine. They are double-cylinder, reversible engines with cylinders 7 inches in diameter and a stroke of 10 inches, using steam at 125 pounds, and safe at 250 pounds.

THE PRELIMINARY OFFICIAL TRIAL.

The standardization trials were made on the Barren Island course in Chesapeake Bay, and the speed trial was run off Cape Henry in free route in the open sea. The bottom was clean and the vessel was in good condition. The coal was the New River, Collins Mine, hand picked. The draught during the trial was, forward, 12 feet $5\frac{3}{8}$ inches; aft, 12 feet 9 inches; mean, 12 feet $7\frac{3}{16}$ inches.

The general results for the standardization runs are:

No.	Direction.	Mean revolutions per min.	Speed in knots.	I.H.P., both main engines for each round run.
1	S.	81.61	5.831	119.106
2	N.	68.69	3.786	
3	S.	121	8.803	403.09
4	N.	120.35	7.997	
5	S.	165.30	10.490	932.35
6	N.	165.56	10.692	
7	S.	212.26	12.470	2,189.86
8	N.	216.74	12.955	

The speed trial took place Tuesday, 7th August, 1902, off Cape Henry, and the following data were taken. The run lasted two hours and the data were taken at half-hour intervals from 12·05 to 1·35 P. M.

Revolutions per minute	starboard, 197.9;	port, 196.3
Mean pressures, H.P., pounds	starboard, 60.1;	port, 38.66
I.P., pounds	starboard, 21.87;	port, 23.83
L.P., pounds	starboard, 10.45;	port, 9.43
Indicated horsepower, H.P.	starboard, 319.20;	port, 203.62
I.P.	starboard, 280.99;	port, 303.60
L.P.	starboard, 313.62;	port, 280.65
total for each engine	starboard, 916.66;	port, 800.72
both engines		1,717.38
Horsepower of circulating pumps		5.70
dynamos		36.63
forced-draft blowers		31.42
main feed pumps		15.70
water service		15.70
fire and bilge		6.06
total for auxiliaries		111.21
all machinery in use during trial		1,828.59
Revolutions per minute, circulating pumps	starboard, 262;	port, 262
feed pumps, double strokes, per minute		29.7
blower engines	starboard, 361.4;	port, 365.6
Speed of ship in knots per hour		12.7125
Slip of propellers in per cent. of its own speed, based on mean pitch	starboard, 9.91;	port, 8.97
Air pressure in fire rooms, inch of water		.5
Steam pressures at boilers, per gauge, pounds		204
high-pressure valve chest	star., 151.8;	port, 139.3
first receiver, abs.	starboard, 54;	port, 54.3
second receiver, abs.	starboard, 20.6;	port, 20.3
Vacuum in condensers, inches of mercury	starboard, 25.5;	port, 26.1
Coal used per hour, pounds		6,720
per I.H.P., all machinery, pounds		3.688
square foot of grate, pounds		33.94
heating surface, pounds		.7175

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NOTES.

ON THE STRENGTH OF HIGH-SPEED VESSELS.

By M. J. A. Normand.

The method employed by Fairbairn of calculating the maximum stresses upon the hull of a vessel does not give a complete idea of its strength.

The resistance offered to statical forces ought not to be solely considered, and in very fast ships the resistance to dynamic forces becomes of much greater importance.

Among the causes producing fatigue which are often overlooked, the following may be cited:

1. *The Degree of Suddenness with which the Force is Applied.*— The effect will be twice as great if the force is applied suddenly. If a weight attached to the end of a spring is allowed to fall quickly, the spring will be extended twice as much as it would be were the weight lowered gently. The destructive effect of quick-burning powders upon the lining of a gun as compared with that of slow-burning powders, even when the maximum internal pressures are the same, can hardly be explained in any other way. Similarly, half the weight of charge suffices to burst a shell by detonation that would be required to explode it by ignition. In each of these cases, the duration of the detonation is sensibly less than that of the transverse vibration of the gun or of the shell.

If a vessel is driven at speed through waves, an analogous effect is produced, and the ordinary calculations of the stresses of the hull on a wave under-estimates them. The calculation should take account of the worst condition, and this is when the bow is plunged in a breaking wave advancing to meet it. If the relative velocities are very great, the resulting forces are double what they would be under statical conditions, because the duration of the force may be sensibly less than that of a transverse

vibration of the hull. It may even be more than doubled, because the vessel not having time to rise to the wave, the excess displacement of the submerged upper works forward will increase the sagging moment tending to rupture the vessel. In addition to these causes of fatigue, the effect of masses of water falling upon the forward part of the deck may sometimes be considerable.

The stresses due to the position on the wave are proportionately increased by the speed. The shape of the hull has also a great influence on the dynamic stresses. When the stern is too flat and the bow sections are not sufficiently fine, pitching motion may be so suddenly arrested as to shake the vessel from end to end. Insufficient immersion of the screws will also cause racing of the engines and severe vibration in the hull.

Too much freeboard forward is also disadvantageous, although it will have the effect of reducing the quantity of water falling upon the fore deck. The best shape of bow is probably a suitably-formed ram.

The scantlings of many cargo boats are very weak. Most of those which run aground at the mouth of the Seine break in two at low water; nevertheless, they can live through very rough seas. They owe their security in a seaway to the feebleness of their engine power, and the great reduction in their speed which takes place in bad weather.

The higher the speed of a vessel, and especially the higher the speed that is maintained in rough water, the stronger the scantlings should be. It is not one of the least of the dangers attending excessive speed that hull weights need to be reduced in order to obtain it, instead of being augmented; and also that the proportion of length to breadth has to be increased when it should properly be reduced.

The high trial speeds demanded of torpedo boats and destroyers tends without doubt to diminish the speed they can maintain in rough water. They would certainly have more chance of escaping from cruisers if, by limiting their smooth-water speed to 25 or 26 knots, they could be made to steam some knots faster in a seaway than they can at present.

The advantage thus gained would outweigh the disadvantage

that they would be unable to catch a few of the fastest torpedo boats in a calm sea.

2. *Vibrations Due to the Inertia of the Moving Parts of the Machinery and to the Propeller.*—These may become dangerous if the impulses synchronize with the vibrating period of the hull. It is no longer a case of suddenly applied forces succeeding each other at such an interval that the effect of each has time to subside before the impact of the next, and of which the maximum effect must certainly be limited to twice that of a gradually applied force. It would seem impossible to affirm, *à priori*, that synchronizing impulses should not more than double the amount calculated for statical conditions.

What appears certain is that it is very desirable to shorten the vibrating period of the hull, and thus increase the value of the extinction coefficient and reduce the chance of synchronism. This period is proportional, other things being equal, to the square root of the static deflection;* and everything which tends to reduce this, such as transverse bulkheads, pillars, &c., increases the strength. It is obviously very advantageous from this point of view to reduce the ratio of length to breadth and depth, for not only is the resistance to statical forces thus increased, but the vibrating period for a given displacement is reduced in the proportion of the $\frac{3}{2}$ power of this ratio. The case is analogous to that of suspension bridges. Old bridges of this type, with flexible cables, were dangerously affected by the passage of a body of troops marching in step. But by introducing rigid suspension members, and thus shortening the vibrating period, so that each vibration is extinguished before the next impulse is felt, American engineers have succeeded in making those bridges serve for the passage of trains.

The importance of the vibrating period of the hull as affecting the strength is due to the possibility of synchronism. It might be neglected, if it were only necessary to take account of shocks due to waves occurring at long intervals. Sailing ships could be strong and flexible at the same time within the limits compati-

* "Des Vibrations des Navires, et des Moyens Susceptible de les Atténuer." (Mémorial du Génie Maritime, 1893.)

ble with watertightness. In a note "On Dynamical Resistance," communicated to the Academy of Science, of which extracts appeared in their Proceedings in 1863, I showed that the resistance of a solid of rectangular section to a transverse blow was the same, whether the solid was placed edgewise or flatwise upon its supports. This is true of a single blow, or of a succession of blows with sufficient intervals between to allow the solid to return to rest between each impulse. It is obvious, on the other hand, that if subjected to a rapid succession of blows, or to a statical force, such as vessels are frequently called on to encounter—by grounding, for example—then the solid will be much stronger if placed edgewise.

3. *The Unequal Distribution of the Load between the Different Parts of the Structure, which should Theoretically be Equally Loaded.*—In light hulls built of very long plates the insufficient leveling of these and the effect of cold riveting may produce local tensions such that two adjacent plates may be oppositely stressed, one being in tension and the other in compression; or, at least, their stresses may be very unequal. This result is, above all, to be feared when the joints of the plates are butted, and insufficient play left at the ends.

From this point of view, the system of lap-butting, such as we employ in our destroyers, is preferable, because it allows of some stretching of the plate during the process of riveting.

The hull of a torpedo boat or a destoyer, after it is riveted, can be compared to some extent to a piece of high-tensile forged steel before it is annealed. Parts of the steel are in a state of tension approaching to the limit of elasticity, while neighboring parts may be under equally severe compressive strains.

It is for similar reasons that the process of tempering which, when properly carried out, improves a gun tube, may be dangerous when the form is irregular and the thickness considerable.

Compressive strains are most to be feared in very light hulls, because the frame spacing in proportion to the thickness of the plates is greater in small vessels than in large ones.

Nevertheless, it is not in close frame spacing, but rather in an increase in longitudinal girders, that a remedy must be sought.

Additional stiffening of this character is imperative, whenever "panting" is observed in a plate due to vibration. Every plate exposed to this dangerous action, whether it be due to local compressive strains, resulting from defective leveling, or to tension produced by riveting, or to its being too flat, is likely to break sooner or later. It seems difficult to attach too much importance to these considerations, which may seem but secondary, and also to the fitting of efficient compensation in places where the strength has been reduced by the cutting of hatches, &c., and thus to ensure uniformity of strength and elasticity. It is for this reason that the section of the plain part of an engine bolt, subject to alternating strains, is turned down to a diameter rather less than that at the bottom of the thread, so that the stretching may take place over as great a length as possible.

The influence of absolute size upon strength is difficult to determine. Other things being equal, the stress upon the material due to statical forces* and the vibrating period are directly proportional to the linear dimensions. From both these points of view, the smaller the dimensions of a vessel the greater should be its strength. A glass bottle will survive in the heaviest seas, and faithfully deliver its message after many months, and even years. But if two similar ships of different dimensions are considered, steaming at the same speed through the same waves, and especially against the same head sea, then other causes incline the balance in favor of the larger ship, and the advantages possessed by the latter become incontestable as soon as the sea is sufficiently rough and the speed high enough to prevent the vessel from following faithfully the undulations, and especially when the speed and the state of the sea are such that the waves which break upon the deck of the small vessel are safely surmounted by the larger one.

It is also evident that at equal speeds the vibrations caused by the engines, which are of such importance as affecting the strength, are more severe in the small vessel, since the weight

* "Bulletin de l'Association Technique Maritime," 1892, page 5.

of the moving parts bears so much greater a ratio to the total displacement.

Besides this, other considerations, such as the safety of the crew, which depends partly on the height of the deck above the water in a rough sea, imposed a limit to the speed of small vessels. For this reason, the flying decks fitted on our destroyers present substantial advantages.

The adoption of high-tensile steel for the construction of the hulls adds to the strength in a greater degree than would be imagined. In the paper already referred to on "Dynamic Resistance," I showed that the strength of any solid to resist transverse blows is proportional to the square of the coefficient of tensile strength and elasticity of the material, while the strength to resist a steady load is proportional simply to these coefficients. If then, as seems probable, the dynamic forces acting on the hulls of fast vessels are of more importance than statical forces, the strength of the hull is more than doubled by the substitution of 39-ton steel for 26-ton steel. The advantage is greater still if the elastic limit is considered which should never be exceeded in any structure.

But in order that this should be the case, the strength of the rivet material must evidently be increased in the same proportion. In an interesting paper on "Torpedo-Boat Destroyers," read at the last session of the Institution of Naval Architects, Mr. Sydney Barnaby regretted to be obliged to rivet hard steel plates with Lowmoor iron rivets. We do not experience the same difficulty in France. Holtzer cast steel of 42 to 45 tons tensile strength when riveted cold retains all its ductility. Joints thus made can be separated by wedges without breaking off the rivet-heads, but it is not the same when the rivets are put in hot, because then the metal is hardened by contact with the cold plate. Rivets of large diameter should be put in hot.

A high-tensile steel, which shall preserve its malleability both when tempered and when annealed—for both these conditions may be met with—would effect a great improvement; and only by the use of such material could complete advantage be taken of the great strength of high-tensile steel plates in large struc-

tures without an undue increase in the section of the rivet. It appears that some alloys of nickel or of manganese should realize the desideratum, because among those that are known some are hardened by heating and quenching, and some by annealing.

In my latest vessels I have made the rivets, contrary to usual practice, considerably superior in strength to the plates, in order to avoid the loosening of the joints by vibration, for when once a joint commences to move it gets worse very rapidly.

Precisely as a "knock" in the joints of a piece of mechanism, such as a connecting rod, increases the stress on the material, so the shaking of a riveted joint will largely increase the stress on the rivets and on the plates.

The section of the rivets and plates needs only to be considered when a joint is subjected to statical forces only; but in order to resist vibration, the surface contact is important.

In proportion as speeds increase, large vessels also are subjected to violent vibrations, and their strength would very probably be augmented by a considerable increase in the size of the rivets. It is well known how difficult it is, even when special care is taken, to prevent the rivets becoming loose in the vicinity of the propellers in large passenger vessels. There is no doubt that the vibration tends to produce a similar effect, although to a less extent, in other parts of the hull. Obviously the desired increase in rivet section should be obtained, not by spacing the rivets closer, which would weaken the plate, but by increasing the number of rows.

JANSON WATER-TUBE BOILER.

Examining the contents of the report submitted to the British Admiralty by the Boiler Committee appointed for the purpose of ascertaining facts about various types of water-tube boilers, it will be found, that some thirty-six different designs and makes were under consideration. Only a few of these, however, were investigated more thoroughly when in service.

Among those enumerated three were of American design, viz: The Babcock and Wilcox boiler, the Hohenstein and

the Janson. The first one named is well known and needs no description, and with regard to the Hohenstein, some very extensive experiments and trials have lately been conducted by engineer officers of the United States Navy, the results of which are published in the 1902 Report of the Engineer-in-Chief. It may therefore be of interest to the readers of the JOURNAL to also know the general features of the last named boiler, designed by Mr. Ernest N. Janson, of the Bureau of Steam Engineering, Washington.

As the present design shows in Fig. 1, the tubes have an incline of from 8 to 10 degrees, due to which, looking transversely, the tube surfaces of the alternate elements almost wholly cover one another, which, as a means of baffling the gases, is of great importance, when it is considered, that the gases of combustion travel across the tubes from side to side, being retarded at each and every exit by tubes running in opposite directions (the gases in that way being thoroughly beaten up). As shown in Fig. 2, the headers with their tubes are clear of one another, thereby providing for any one tube or element being withdrawn, in case of damage, without disturbance to adjoining elements. With this arrangement is also gained larger openings between the tubes and headers for the insertion of cleaning tools, and increased facilities for a thorough cleaning of any part of the boiler from the firing side. The complete absence of any return bends in the generating tubes insures a direct and very rapid circulation of water and steam, clearly indicated by the arrows shown in Fig. 1.

The top and bottom bafflers having a direct support on the tubes, and, being composed entirely of fire brick, will remain intact, no distortion being apt to occur owing to the absence of any perishable attachments. In case of damage they are easily replaced. Drain and bottom blow-off connections are attached to the large square tubes placed at the middle of each drum, which tubes also act as intermediary supports to take the weight in conjunction with the saddles, built in the casing at each end.

When the boiler is of a great width, by the leaving out of a few tube elements in the middle, or at either side, when of a

narrower type, a fair-size combustion chamber may readily be provided for. Of course, by doing this, some portion of the heating surface is sacrificed, but this may well be done, con-

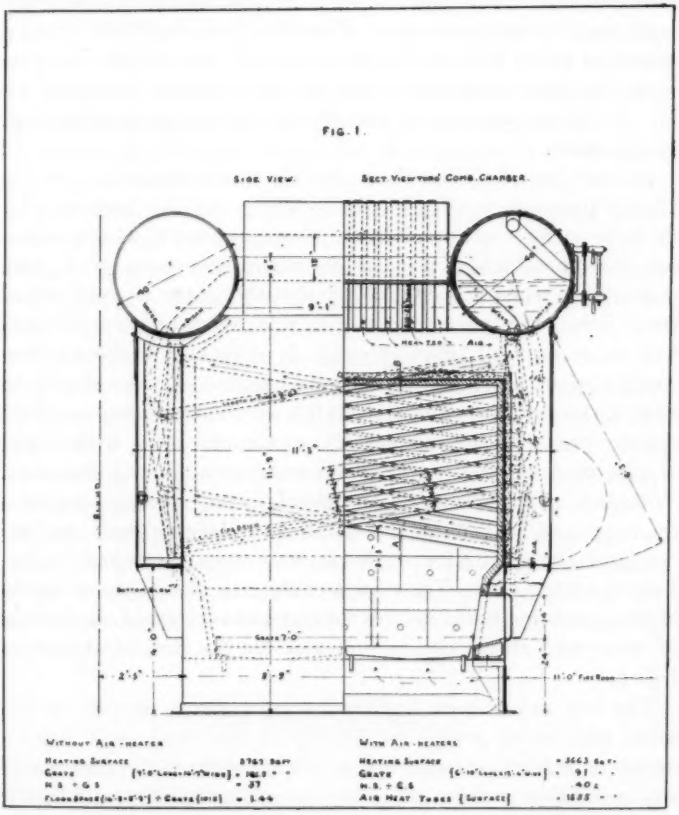


FIG. 1.
SIDE VIEW.
SECT. VIEW THRO' COMB. CHAMBER.
9'-1"
11'-3"
Grate 7'-0"
2'-5"
8'-9"
11'-0" Fire Room
WITHOUT AIR-HEATER
HEATING SURFACE 3763 Sq. Ft.
GRATE [11'-0" Long × 10'-3" Wide] = 112.8 " "
H. S. ÷ G. S. = 33
FLOOR SPACE [10'-3" × 8'-9"] ÷ GRATE [ditto] = 1.04
WITH AIR-HEATERS
HEATING SURFACE = 3663 Sq. Ft.
GRATE [11'-0" Long × 10'-3" Wide] = 91 " "
H. S. ÷ G. S. = 40.4
AIR HEAT TUBES [SURFACE] = 1885 " "

sidering the manner in which the gases play over the tubes, rendering the whole heating surface efficient.

Fig. 3 shows the details of the headers and tube caps, which are all entered through the hole at the bottom of each header which is afterwards closed with a brass plug. The doors closing

the openings, through which the boiler is cleaned, are shown with a pipe attachment for blowing off the soot with steam. All these doors open and close at the same time when turning the con-

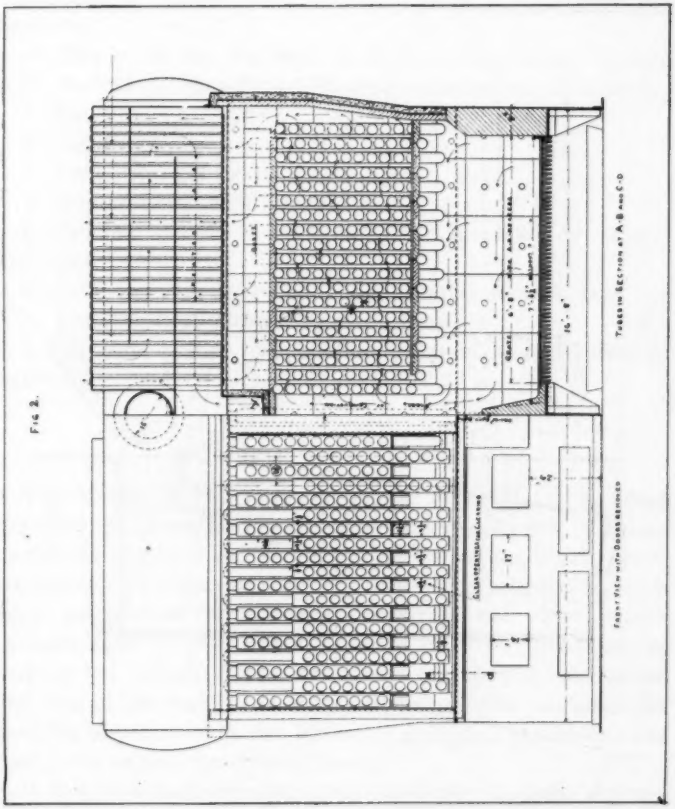
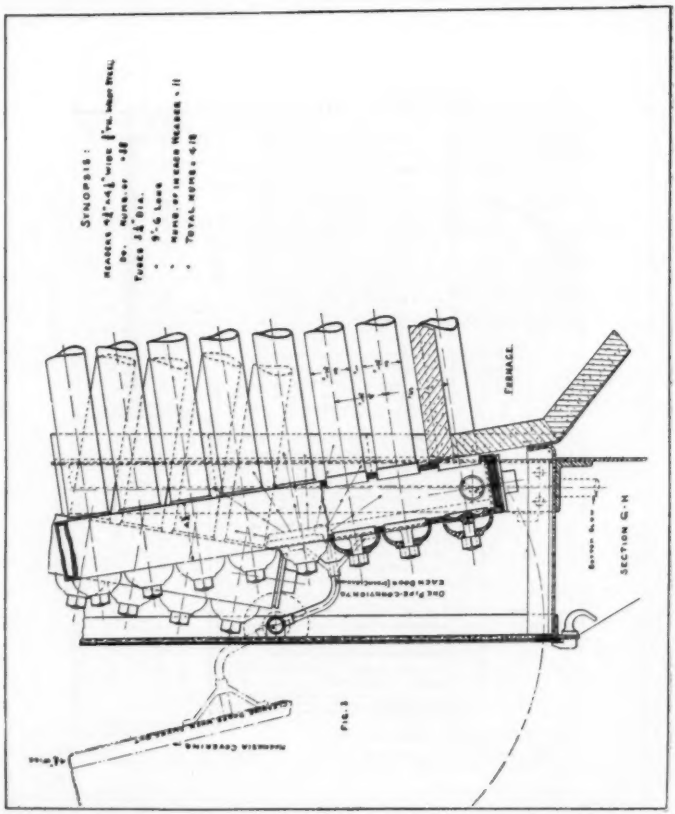


Fig 2.

necting pipe *P*. All the lower headers are connected by means of short pipes between them at the bottom for the purpose of drainage only. This boiler is particularly well adapted for the attachment of a hot-air apparatus, either on the Howden or Ellis and Eaves system; being placed between the drums in the

uptakes, no additional space, outside of what the boiler already occupies, is required.

Constructively the boiler is quite simple, the headers all being



of a square, straight form, and the tubes all of the same size and of a large diameter. This being so renders its manufacture well within the capacity of any well-equipped shop.

Besides the recognized advantages of using large-diameter tubes for water-tube boilers, it follows that the number of parts

necessary to be handled at the time of examination and cleaning are reduced to a minimum, and for that reason work in connection therewith much facilitated. Appliances for burning liquid fuel may readily be attached with either front or side connections.

As this boiler has not been tried on a large scale, it is now only possible to note some of the mechanical points of interest:

1. Easily manufactured.
2. Lightness.
3. Large, straight tubes.
4. Wrought steel all through.
5. Cleaning possible from firing side; accessible for repairs and examination.
6. All tube joints expanded, metal-to-metal joints in caps.
7. Rapid circulation and large water reserve.
8. Complete system for baffling gases with non-perishable bafflers.

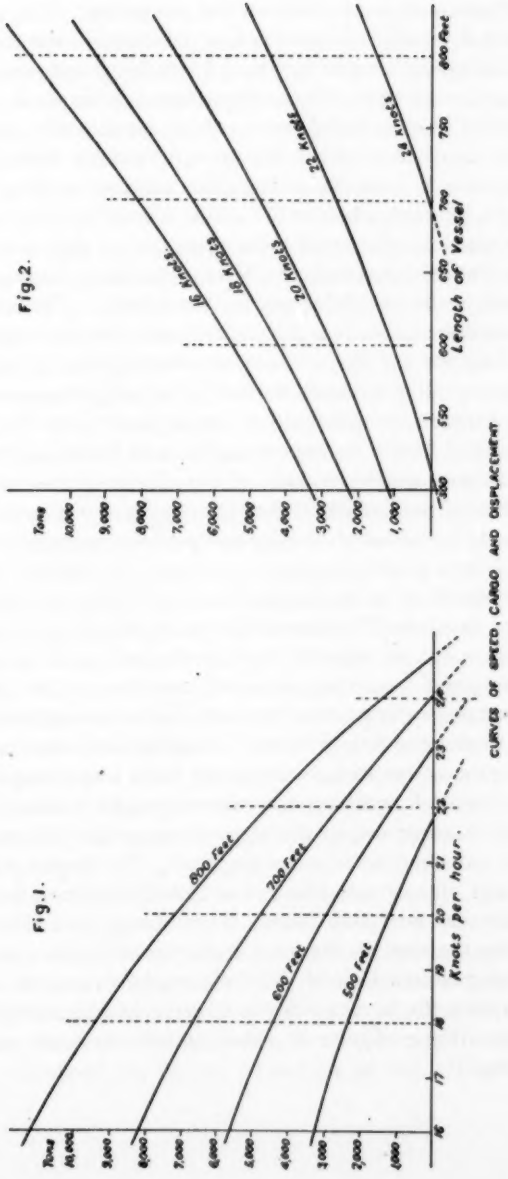
NEW ATLANTIC LINERS.

The reason for the enormous expense of vessels of the ocean express type and their small profit-earning capacity lies, of course, in the fact that high speed means powerful engines which, again, require a large supply of fuel, both of which requirements necessitate an increase in the displacement of the vessel, which increase again requires more power to drive the vessel at the given speed. Each of these items has a tendency to increase the first cost of the vessel, and the coal consumption increases the working expense, while the increased weight of machinery and coal go to reduce the earning powers.

It is a comparatively easy matter to design a cargo steamer where the weight of the hull, machinery and coal may be only about 40 per cent. of the total displacement, leaving 60 per cent. as the weight at the owners' disposal. If the worst comes to the worst, an error of 1 or 2 per cent. in the weight of hull and machinery only means that the cargo-carrying capacity is reduced by as much. But when, as in the high-speed Atlantic liners, the

weight of hull, machinery and coal supply may amount to as much as 95 per cent., leaving only 5 per cent. of the displacement at the owners' disposal, it is then clear that the question of a little more or less weight is of the greatest importance. Displacement is, in the first instance, the material which a naval architect has at his disposal in designing a ship, and the less he needs of it the better. A certain part of the displacement must be set apart for the hull of the vessel, and the weight of the machinery and coal must come out of the remainder. As the speed increases the weight of machinery and coal increases, and swallows up the spare displacement, until at some point there is nothing left. The limit of speed has then been reached for that size of vessel. If higher speeds are required, larger vessels are necessary. In the fastest Atlantic liners this limit of speed has practically been reached, and an increase in size is therefore always to be expected when there is to be increase in speed. In the case of the *Umbria* and *Etruria* the speed was 20 knots, which was practically the limit for that size and type of vessel, in so far as it only left a few hundred tons of displacement at the owners' disposal when hull, machinery and coal had been provided for. In the case of the *Campania* and *Lucania*, when the speed was raised to about 22 knots per hour, the limit was again reached, in so far as only about 1,000 tons of displacement would probably be left for cargo, stores, etc. The *Campania's* dimensions are 600 feet by 41.5 feet, and the weights may be assumed to be made up as follows, viz: Hull, 10,000 tons; machinery, 4,000 tons; coal, 4,000 tons; and cargo, 1,000 tons, which gives a total displacement of 19,000 tons, say, on a draught of 27 feet. Figs. 1 and 2 will give an idea of the relation between speed and size in the case of vessels of the *Campania* type, as regards relative weight of hull and weight of machinery and coal per indicated horsepower. Fig. 1 shows the cargo-carrying capacity for varying speeds of vessels 500 feet, 600 feet, 700 feet and 800 feet in length.

It will be observed that for a given size of vessel the cargo-carrying displacement is rapidly vanishing with the increased speeds. The curve for the 600-foot vessel corresponds to the



CURVES OF SPEED, CARGO AND DISPLACEMENT

weights assumed in the case of the *Campania*. The curve for the 500-foot vessel corresponds to a reduction in the dimensions of the *Campania* to 500 feet by 58 feet by 37 feet, the draught being 24 feet molded. These dimensions correspond nearly to those of the *Umbria* and *Etruria*, which are actually 500 feet by 57 feet 2 inches by 40 feet, the draught molded being 24 feet. At a speed of 20 knots the curve gives a cargo-carrying capacity of about 1,100 tons, whereas the actual amount in the case of the *Umbria* was less than half this, owing to the difference in type between the *Campania* and *Umbria*, the latter having a finer form and proportionately heavier machinery. The other two curves correspond to increased *Campanias*, the assumed dimensions being 700 feet by 71 feet by 45.5 feet and 800 feet by 76 feet by 48.5 feet. Fig. 2 shows the cargo-carrying displacement for varying lengths for speeds of 18, 20, 22 and 24 knots per hour respectively. It will be seen by a glance at these diagrams that, if the relative weight of hull of the *Campania*, or the weight of machinery per indicated horsepower, or the amount of fuel consumed per indicated horsepower per hour cannot be reduced, then a vessel would require to be over 750 feet in length to obtain a speed of 24 knots per hour, which the new vessels are expected to attain. This shows the great difficulties of the problem, and it will be apparent that the desired result is not likely to be obtained by simply enlarging the size of the *Campania*. The diagrams indicate how the speed could be obtained by the mere advantage of size of vessel. The other, and more preferable, way to gain an increase in the speed is by improving the older designs through reducing the relative weight of machinery per indicated horsepower, or through reducing the consumption of coal per indicated horsepower per hour. The former way is the broad and clumsy one, that can always be resorted to more or less, when the necessary money is provided. The latter way of increasing the speed is the more ingenious and refined, and shows the greater or less skill of the designer, by the extent to which it supersedes the former, and its adoption marks a distinct step forward in the evolution of naval architecture and marine engineering.

When there has been an increase in the speed of Atlantic liners, it has therefore not usually been obtained by a mere increase in size over and above the last previous vessel, but by an increase in size combined with the improvements in construction of hull and machinery introduced since the last vessel was built, in conjunction with such improvements as the designer was able to introduce, and had the courage to initiate, in the particular steamer. There is no doubt that the same thing will again occur, now that a further increase in the speed is to be made. There will be improvements in the design, which will make it possible to obtain the speed on a relatively smaller displacement than was previously required, but there will, in addition, almost certainly be a considerable increase in size over that of the fast German steamers, for the Cunard Company is known always to insist on a very strong and substantial construction, which can hardly be obtained except in conjunction with additions to the dimensions of the vessels. The displacement must in these large steamers unfortunately be obtained subject to a limitation as to draught of water, a consideration which seriously hampers designers. When the necessary displacement cannot be partly obtained by addition to the draught, it must be chiefly obtained by increasing the length of the vessel, as the breadth cannot be materially increased without an addition to the depth and draught. A proportionately long vessel means a proportionately heavy hull, and the limitation as to draught is therefore one of the most serious elements in the design of large vessels. The harbor boards and dock companies are in this respect lagging behind, as they do not provide water enough to enable the ship designer and shipowner to utilize a given displacement to its best advantages.

In the case of the *Umbria* and *Etruria* the draught of water was 25 feet. The *Campania* and *Lucania's* designers were able to go to about 27 feet. It is probable that a similar increase can be made now, so as to enable the new vessels to draw 29 feet. It is not likely that the displacement will be far short of 27,500 tons, to obtain which on a draught of 29 feet would require the dimensions to be about 725 feet by 72 feet by 48 feet. The indicated

horsepower necessary to drive a vessel of this enormous size at a speed of 24 knots per hour will be about 50,000, and the weight of coal for a single trip will be about 6,300 tons. It is not likely that, even on these large dimensions, much more than a thousand tons would be left at the disposal of the owners, and it will be of great interest to see what modifications will be introduced in order to obtain the speed on these dimensions, or whether it will be at all possible materially to reduce the above displacement. It is not probable that any very radical changes in the design of either ships or machinery will be introduced. It is more likely that the necessary displacement will be obtained by strict economy with regard to weight throughout both hull, engines and boilers.

The creation of a ship is from end to end dependent on compromises, and in no respect does it attain the ideal. The type which has the greatest number of points in its favor, and the fewest against it, is the one that must be adopted, and it seems that such a type has been fairly established in the case of large passenger steamers, as they are now nearly all being built with a complete promenade deck, with more or less open sides between the poop and forecastle, and with a tier of deck houses above. This arrangement is very comfortable for the passengers, as it provides plenty of light and open deck spaces. It has, however, the serious structural objection, that the superstructure of the promenade deck cannot be efficiently incorporated with the remainder of the hull so as to contribute to the strength of the structure. Being situate at the place where the main structural stresses are greatest, and being unable to be made capable of resisting these stresses, it must necessarily strain and cause trouble by leaks in the decks, unless provision is made to prevent any stresses being transmitted to the promenade deck by severing it, and providing a kind of expansion joint at various places, as has been done in some recent vessels. The fact that the feature of the promenade deck commends itself so much to the passengers will, however, almost certainly be sufficient to cause it to be retained in the new vessels.

The most serious stresses in these long and fine-ended vessels

are those due to bending from excess of weight at the ends and an excess of buoyancy amidships, and by far the greatest weight of any single item in the structure has to be provided to meet these stresses. All unnecessary weight at the ends is therefore not only occupying useful displacements, but is in itself a source of additional stresses, which could be avoided, and the material or weight required to meet them therefore saved. Everything tending to move the weights of the structure from the ends towards amidships will, therefore, in this type of vessel go to reduce the stresses, or, rather, may make it possible to reduce the material while retaining the same strength. It is possible that something may be attempted in this direction in the new vessels by reducing, or even dispensing altogether with, the sheer. The freeboards at the ends of these vessels will be so great that there cannot be much necessity for adding to it by sheer. The question of appearance will probably, to conservative designers, be a more serious objection, which, however, ought to yield to more important considerations. It is, after all, a question whether the absence of sheer would detract seriously from the appearance of vessels of this type, if other features were modified to be in harmony with the change. Such an innovation would, under any circumstances, have many advantages. It would not only reduce the weight of the structure and cargo at the ends, but would convey the material to the midship part of the vessel, where there is ample—in fact, too much—displacement to carry it. The modification would further increase the depth of the structure amidships, thus giving additional strength without reducing the stability of the vessel. The weights of the engines and boilers might also with advantage be concentrated as much as possible amidships; but it is not probable that it will be possible to do much in this direction, nor is it likely that the position of the coal bunkers will be determined by structural considerations, although the removal during the course of a voyage of such an immense weight of coal from the midship part of the vessel affects seriously the main stresses on the structure. As the size of vessels increases, it is becoming more likely that some such attempts as have been indicated will be

resorted to with a view to neutralizing the serious effect of the extreme proportions necessitated by the limitations of draught, or the equivalent result may possibly be arrived at by extending the main structure to the promenade deck for part of the length amidships.

With regard to the underwater form of the new vessels, it is also improbable that radical changes will be made. The restriction on the draught is here again a serious drawback, as it necessitates a very full, square bilge form amidships. If there existed no limitation in this respect, then the form would probably approach more closely to that of the fast torpedo-boat destroyers, with their higher rise of floor and easier bilges, and higher speeds would hence be obtained without increasing the displacement. The earlier fast Atlantic liners, such as the *Umbria* and *Etruria*, were of a comparatively fine form amidships; but in the more modern craft, such as the *Campania* and *Lucania*, the fuller form at the bilge had to be adopted. The excessive concentration of the displacement amidships is an evil both from the point of view of the strength as well as of speed, but it is one which must be faced until docks and harbors are considerably deepened. With regard to the finding of the form of least resistance, subject to the restricted draught, it seems a pity that none of the shipbuilding firms likely to undertake the building of these important vessels should possess a tank where model experiments could be made, and the form be found which would require the minimum of power for the required displacement and speed. Better results might thereby possibly be obtained on a given displacement. Under any circumstances, the required power might be determined with a greater degree of certainty, and the want of such a tank places nearly all our builders at a disadvantage in competing with, at any rate, the North German Lloyd's Company. Such a tank is, of course, of increasing value, as speeds are growing, and it is particularly so where great departures are to be made from previous practice. In the case of the lower speeds the resistance depends more upon the friction on the wetted surface, and less on the vessel's form. But with the higher speeds the wave resistance becomes an im-

portant factor, and consequently modifications in the form, which are apparently trivial, may have serious effects on the speed.

From what has been said it will be seen that the improvements and modifications from previous practice in the construction of the hull of the new vessels are most likely to be found in a general tendency to economize weight without sacrificing strength, and as it will probably be found impossible to reduce materially the scantlings of the main items, such as the shell plating, steel decks, etc., a considerable reduction may have to be effected in parts of minor importance, and no doubt this can be done without reducing the general standard of efficiency. With regard to the building material, it is improbable that any departure will be made from the ordinary mild steel. The specially high tensile qualities of steel are probably too expensive for general use, and until some means have been found for correspondingly improving the riveting of the attachments, they will be of comparatively small value for the plating of such vessels as those being considered.

The remarks made with regard to the hull are equally applicable to the propelling machinery. It is not probable that in them either will any startling changes from previous practice be found. Attempts will doubtless be made to reduce the weight of machinery and the coal consumption per indicated horse-power, and other improvements will be introduced in respect of details, but, on the whole, the engines and boilers will probably be enlarged editions of what have been before. Some very radical changes might, indeed, have been possible with regard to the propelling machinery upon the lines being adopted in some much smaller steamers. They are, however, hardly sufficiently ripe to be adopted at the present moment in such large and important vessels as the new Cunard liners. The turbine engines will, perhaps, in time replace the reciprocating machinery in high-speed vessels; but so far this method of propulsion has only been adopted in two torpedo-boat destroyers, a yacht, and two passenger steamers for service in sheltered waters. It would, however, be a bold step to introduce the system in a large liner, although temptation to do so might be great in view of the

chance of obtaining an excessively high speed, together with a great reduction in the unpleasant vibrationary movement which at present is so often experienced. Water-tube boilers have, of course, been now used in war ships for a long time, and a large amount of weight is certainly saved under some conditions by their adoption; but, so far, there has not been found a type so well suited to the requirements of the mercantile service as the orthodox Scotch tubular boiler, and consequently the latter type is pretty certain to be adopted, in spite of its greater weight.

A third possible innovation is that of burning liquid fuel. This is gradually becoming more common in certain types of steamers, but it, too, has not, so far, been applied to large liners, although it would be particularly advantageous in that class of vessel. The oil would take much less space than the coal, and would also weigh less, in addition to which the enormous number of stokers at present necessary might be reduced. At present there are, perhaps, difficulties in obtaining in the proper places a regular supply of such tremendous quantities of oil as would be required for a liner's trip across the Atlantic. The cost, too, may at present be a bar to the adoption of liquid fuel. It does, however, seem a pity that the designers should not just now be able to take advantage of any of these important innovations in marine engineering.

As regards the propellers, *it is just possible that three might be adopted instead of the usual two*. If two only are adopted, then the horsepower on a single shaft will be increased considerably over what has hitherto been attempted. In the case of the *Umbria* and *Etruria*, with single shafts, the indicated horsepower is a little over 14,000. In the *Campania* and *Lucania* it is about 15,000 on each shaft, but in the new vessels it would have to be something like 25,000.

It will be interesting to see to whom will fall the honor of building these vessels, which will be the embodiment of everything that is foremost in naval architecture, and which will be the center of interest to the profession for the next few years at any rate. Even to engineers outside the shipbuilding profession, the construction of these vessels will be a matter of great interest.

Already there are proposals for the widening of rivers to enable the vessels to be launched. The question of deepening docks and harbors may have to be considered, and in a hundred other ways the construction of such vessels will affect engineers who are not directly connected with ship construction.—London "Engineer."

SUBMARINE VESSELS.

Sir Edward Reed, M. P., a former Director of Naval Construction for the British Navy, supports the view that the submarine will have its classes in years to come just as there are various types of cruisers and other torpedo craft. Already the increase in the size of the newer British boats appears to give confirmation to his opinions. His belief is that we shall have three kinds of submarines:

1. Vessels for the defence of ports and harbors with sufficient means of proceeding outside to give the defence a certain limited power of attack in the approaches.

2. Vessels primarily designed for attack, and, therefore, capable of proceeding to sea for considerable distances.

3. Smaller vessels to be taken to sea in ships as part of their equipment, and capable of being lowered to take part in a battle and raised again and re-stowed on board when no longer needed in action.

It is along these triple lines that development is proceeding. In the *Goubet* we have a submarine of the last class, small and light; in the latest British boats of the Holland type we have the beginning of the sea-going submarine, and in the original smaller vessels, such as were delivered at Portsmouth, we have the kind for harbor defense. When the *Goubet*, or some other small submarine is installed in a British man-of-war, the spectacle will be a curious study. First, there will be a battleship of from 16,500 to possibly 18,000 tons, with engines developing, maybe, 30,000 indicated horsepower. She will carry the *Goubet*, displacing only one ton of water and able to go twenty-five miles, and the *Goubet* itself will carry another ship—the torpedo, which

is really nothing more or less than a cigar-shaped, self-propelled vessel. A ship within a ship, and that ship within a yet larger ship. Each submarine of the type delivered at Portsmouth costs from £25,000 to £30,000, displaces 120 tons, and carries four torpedoes 11 feet 8 inches long.

The submarine has taken its place in the British fleet, and its presence in the French squadrons has been demonstrated by the successful torpedoing of several ships. Not more than two or three years ago it was the fashion to scoff at this new craft, but that day has passed. Henceforward these latest types of specialized ships, depending for their efficacy entirely on the torpedo, and thus unlike every other class of ship in the fleet, and devoid of any protection against attack beyond their power of diving, will have to be reckoned with. Until the next naval war has settled many problems, the moral effect of the submarine will be great. They are really merely torpedo boats which can dive beneath the surface, and travel thus for four hours on end, meantime, it may be passing unseen from Dover to Calais—the electricity is more than sufficient for the purpose—without being once seen or their presence suspected by the most watchful observer. Seven knots is their underwater speed, and on the surface they can go 400 knots with their petrol engines at eight knots an hour. This radius of action is being increased, and the speed in the early boats of eight knots is also being augmented. They have an apparatus, invented by Sir Howard Grubb, which gives them a limited power of vision when submerged.

In short, the submarine has come, and it has come to stay. Its evolution from a mere scientific toy—interesting but useless—to an engine of warfare with accurately defined powers, has already reached a stage when it seems possible to trace the course of adaption in the near future. We have practically given up carrying torpedo-boats in battleships, but it is probable that we shall yet see every vessel likely to participate in a battle or in any such loose blockade as may be possible in future war, provided with a couple of these craft—small, light, but capable of being dropped in a normal sea.—" Engineer's Gazette."

IMPROVEMENTS IN SHALLOW-RIVER NAVIGATION.

The systems of propulsion available for shallow-river navigation are:

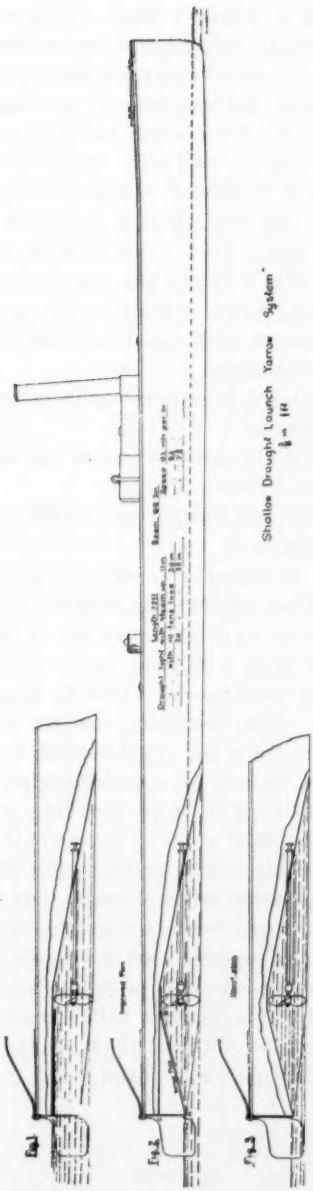
Firstly, by paddles, one being placed on each side of the vessel, which system is familiar to everyone accustomed to travel on European rivers.

Secondly, the stern-wheel system, the paddle wheel being in this case placed at the stern of the hull. This plan is adopted to a large extent on the rivers of North and South America. Both these systems have the disadvantage of reduced efficiency when the vessels are loaded and consequently deeply immersed, unless feathering wheels are adopted, which is a device costly to maintain in good working order. Also the weight of this class of machinery is great and the space occupied considerable as compared with a screw-propelled vessel. Moreover, the wheels, especially in the side-wheel system, are exposed to damage by floating timber, and in any case the width of channel required with a side wheeler is increased by the width of the wheels.

The ordinary screw-propelled vessel is not applicable when the draught is very limited, on account of the want of ample immersion for the propeller to secure efficiency. There is a third system of propulsion for shallow-river navigation, consisting of an arrangement of screw propeller which has been brought forward prominently of late; it combines the advantage of a large propeller combined with a shallow draught. The propeller (or propellers in the case of twin or triple screws) revolves in a tunnnel formed in the bottom of the hull, near the stern. The upper part of the tunnel is considerably above the water line. This tunnel is semi-circular at the top, and dies away forward towards the midship of the vessel, and also towards the stern aft, the propeller revolving in the tunnel at its highest part, the height of the tunnel at this place being a trifle greater than the diameter of the propeller, so that its lower blades are slightly above the bottom of the boat, and therefore there is no risk of their striking the ground. When the boat is at rest the upper part of the tunnel above the water line is filled with air, the water line in the tunnel being level with the water outside, but the moment the pro-

peller commences to revolve the air is driven out of the tunnel and replaced by water; thus it will be seen that a propeller whose diameter is in excess of the draught of the vessel is enabled to work efficiently in a solid column of water, although not projecting below the bottom of the hull. This system has been adopted in modern times to a considerable extent, notably in a number of shallow-draught gunboats built for the British Admiralty for service in East Africa, on the Nile, and, more recently, on the China rivers. The two last gunboats of this type that have been sent out to the East bore the names of the *Teal* and *Moorhen*. For gunboats there is no doubt this system offers special advantages, but for cargo-carrying purposes, or for towing, where there may be large variations of draught, it involves a loss of efficiency when the vessel is loaded, owing to the after end of the tunnel being lower than is required at the deep draught, the rush of water from the screw striking this inclined surface, thereby forming a serious drag. At the same time when the vessel is in its lightest condition it is necessary that the after end of the tunnel should terminate below the level of the water, otherwise air will gain access to the tunnel and completely upset the system, because in the event of air being admitted the propeller no longer works in solid water.

Now the improvements recently introduced by Messrs. Yarrow & Co. secure considerably increased efficiency in the loaded condition of the vessel and admit of large variations of draught. The after part of the tunnel works on a hinge, so that it can be raised or lowered to suit variations in the immersion of the vessel, the after end always being a trifle below the water level. It is easy to understand with this arrangement that the minimum inclination of the top of the tunnel to suit the conditions of draught can be adopted, and the serious reduction of efficiency due to the inclined surface of the tunnel is materially diminished; when the vessel is loaded so that its draught equals the diameter of the propeller the reduced efficiency due to the rush of water striking the inclined surface of the tunnel is entirely avoided, as the after part of the tunnel would, in this case, be horizontal. The design shows a longitudinal section of the vessel


Shallow Draught Launch Yarrow System
1/8 = 1ft

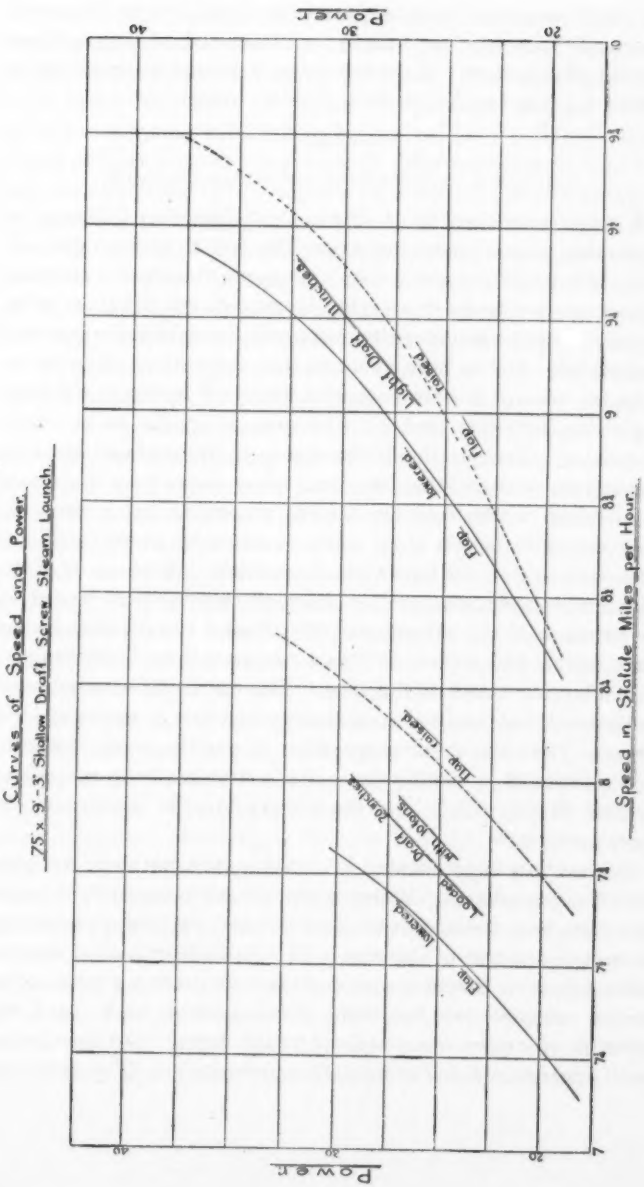
recently tested. It is 75 feet in length by 9 feet 3 inches beam, and has a draught of 11 inches with steam up but without cargo. A complete series of experiments were made to ascertain exactly the advantage due to the variation of inclination of the after part of the tunnel. It will be seen from Fig. 2 that the flap A, B, forming the upper part of the tunnel, moves on a center, B, and when raised up to a horizontal position the point A coincides with the point C. The usual plan is shown on Fig. 3, the after part of the tunnel being fixed. Fig. 1 shows the flap raised to its fullest extent; Fig. 2 shows the flap lowered to its fullest extent, corresponding to the maximum and minimum draughts of water. The curves of speed and power have been worked out for all conditions of draught.

The draught light with steam up was 11 inches, and the speed $9\frac{1}{2}$ statute miles an hour.

With 10 tons load the draught was 20 inches, and the speed was $8\frac{1}{4}$ statute miles an hour.

With 20 tons load the draught was 28 inches, and the speed $7\frac{3}{4}$ statute miles an hour.

Now, taking as an example an average load of 10 tons, the same power is required with the flap lowered (which corresponds to the usual form of construction) to get $7\frac{1}{2}$ miles an hour as with the flap raised gives 8 miles an hour. That is to say there is a gain by raising the flap of $\frac{1}{2}$ a mile an hour, the power remaining the same. Now, assuming that the power required is proportional to the cube of the speed—which is nearly correct—the relative efficiencies will be approximately as 4 is to 5; that is to say there will be a gain of 25 per cent. It was the loss of efficiency due to the water striking the inclined surface that has probably prevented this system being more extensively adopted for vessels having variations in draught, but this difficulty, it will be seen, has been avoided by the present device, and Messrs. Yarrow & Co. are of opinion that for light-draught steamers this system of propulsion will probably become extensively adopted, because by this means a better combination of speed and shallow draught is obtained than by any other, together with efficiency with large variations of load.


Curves of Speed and Power.
75 x 9'-3" Shallow Draft Screw Steam Launch.
Power
Speed in Statute Miles per Hour.
Light Draft
Immersed
Loaded
Deep
Trial
Deep
Immersed
Loaded
Deep
Immersed
Trial
Light Draft
Immersed
Loaded
Deep
Immersed
Trial

It will be noticed that the propeller, owing to its being enclosed all round by the hull, is free from risk of damage from floating obstructions; at the same time it is readily accessible by means of a door placed at the top of the tunnel.

CORROSION OF BOILERS BY MAGNESIUM CHLORIDE.

A paper published by H. Ost in the "Chemiker Zeitung" of September 3 once more emphasizes the fact that the rapid advance in organic chemistry does not appear to leave our chemists the necessary time to thoroughly investigate the behavior of inorganic compounds under circumstances of considerable practical importance. It has been assumed that magnesium chloride attacks the iron of boilers because it splits off hydrochloric acid. Ost contradicts this, and his experiments appear to be fairly conclusive. The question is interesting to the engineer, because magnesium salts find their way into many rivers from the refuse of chemical works, and are always present in sea water. A. Wagner conducted (in 1875) some experiments on the action of salts contained in the feed-water for boilers. Working at ordinary atmospheric pressure, he observed that the iron rusted in the presence of the chlorides of the alkalies and alkaline earths when the air had access. When air was excluded, only magnesium chloride attacked the iron. The corrosion was not well understood then, and was conveniently ascribed to some catalytic action. The chloride of magnesium, it was afterwards thought, is decomposed in boiling water, but not unless it be present as hydrate $MgCl_2$, $6H_2O$, and the temperature be above 105 degrees centigrade.

Ost has only experimented in closed vessels, not to be troubled by ordinary oxidation. Water in which some magnesium chloride was dissolved, distilled from glass vessels, was always found to be neutral and free of chlorine. The distillate remained neutral when copper or tinned copper boilers were used at a pressure of several atmospheres; but some decomposition took place, for some tin or copper was dissolved by the water. Ost then had a small experimental boiler specially constructed in Krupp's works,

at Essen. It is a horizontal cylinder with hollow bottom, pressed out of a block of Siemens-Martin steel, and closed in front by a flange and a steel plate, packed with lead. The capacity of the boiler is 2.6 liters (0.55 gallon); it was generally charged with 2 liters of water, and the heating by gas burners continued until 1 litre of the water had evaporated. The temperature was 183 degrees centigrade (361.4 degrees Fahrenheit), corresponding to a pressure of 10 atmospheres. After each experiment, the inside of the boiler was found coated with a black adhesive crust of the iron oxide Fe_3O_4, a mixture of oxide and protoxide. This oxidation he describes to a decomposition of water into hydrogen and oxygen, which takes place whenever the hot feed-water comes in contact with the bare iron. Ost does not refer to electrolysis; some might possibly occur. The water was charged with 10 per cent. solutions of various salts. The generation of hydrogen was most energetic, up to 123 cubic centimeters of hydrogen being determined in 144 cubic centimeters of gas collected, in the presence of $CaCl_2$, KCl, and K_2SO_4. But no iron was dissolved in these cases, except when $MgCl_2$ or $MgSO_4$ were present: the chloride of magnesium dissolved up to 142.5 milligrams of Fe per liter of the 10 per cent. solution. Now, we do not understand how $MgSO_4$ could split up acid, and none was observed in the case of $MgCl_2$ either, although the steam pressure was high. In Ost's opinion, the attack of the iron is primarily due to the decomposition of water; the oxygen oxidizes the iron, and the magnesium salt reacts with the protoxide of iron, so that some iron is dissolved, while magnesium hydrate is precipitated. This reaction takes place according to the formula: $MgCl_2 + Fe(OH)_2 = FeCl_2 + Mg(OH)_2$. The sulphate $MgSO_4$ would react similarly. In neither case is the reaction complete, however; that is to say, the reaction proceeds in either direction, to the left or the right, until equilibrium is established.

In support of this view, Ost treated iron with hot solutions of magnesium salts in glass vessels on a water bath, where the temperature could not rise above the boiling point. Similar experiments were conducted with various irons and steels obtained from the Krupp works, including nickel-steel, and also with

flower wire and the finely-divided iron employed by pharmaceutical chemists. They all generated hydrogen, the finely-divided iron most, as was to be expected; the nickel-steel and weld iron least. The more sulphur the iron contains, the more easily it will be attacked; silicon, phosphorus, manganese, and also carbon seem to protect the iron; but this point appears to require further investigation, and the behavior of the iron changes with the steam pressure. Thus magnesium salts, and especially magnesium chloride, are injurious to boilers, though probably for different reasons than are generally assumed. There is a remedy, however. At higher pressures magnesium chloride and calcium carbonate interact, forming calcium chloride, which does not attack the iron, magnesia, which falls out as mud, and carbonic acid, which escapes. This escape of carbonic acid gas begins at low steam pressures; and though the reaction is never complete, it would appear from Ost's experiments in his boiler that a little carbonate of lime suffices to prevent the corrosion of the iron by the magnesium salt; he estimates that we need only a quarter as much carbonate as we have magnesium chloride. The precipitated magnesia does not swell the bulk of the scale, as an equivalent amount of calcium salt is dissolved. Some of the rivers, whose contamination with magnesium chloride induced Ost to investigate the subject, contain a sufficient amount of carbonates and bicarbonates to render the water harmless as feed water from this point of view, though we have to fear formation of rust owing to the decomposition of water by the iron. In sea water we have no natural carbonates as a remedy, and the detrimental action of the magnesium salts always present is therefore unchecked.—London "Engineering."

HON. C. A. PARSONS ON THE STEAM TURBINE.

At the meetings of the British Association, which have just concluded, great interest attached to a paper read by the Hon. C. A. Parsons on "Steam Turbines," and the discussion that followed it was certainly animated. The lecturer, in the course of his paper, said that the steam turbine was first used for driving

dynamos in 1884, and in 1890 about 360 plants had been set to work, varying in size from 4 H.P. to 120 H.P., the total aggregate at the latter date being about 5,000 H.P. At the present time 800 turbo-plants had been sold, aggregating 200,000 H.P., the largest being 3,000 H.P. On the continent, Brown, Boveri & Co., of Baden, Switzerland, who took up the manufacture in 1900, had sold twenty plants, the largest being of 5,000 H.P. The British Westinghouse Co. had lately contracted with the Metropolitan District Railway Co. for the supply of ten turbo-alternators of 5,000 H.P. each, and several plants of moderate size had been built by the Westinghouse Company of Pittsburg. The total of all compound parallel-flow turbines at work and on order for generating electricity amounted to an aggregate of about 300,000 H.P. The steam turbine compared favorably in regard to economy with the ordinary steam engine in the generation of electricity. The steam consumption was generally less, and the running costs, notably the up-keep, expenditure on oil, and the attendance, were also less. There was also generally a saving in first cost of the plant, in the housing and in the foundations. The lowest consumption so far recorded had been 17.31 pounds of steam per kilowatt hour with a 1,000-kilowatt continuous-current plant; this corresponded to about 10.21 pounds of steam per indicated horsepower per hour. The author anticipated that a still lower steam consumption would be reached in large turbines working with superheated steam and a good vacuum.

In regard to the question of durability, he stated that several turbine engines had been tested after being at work for a considerable time, and no increase in steam consumption could be detected. Seven vessels had been fitted with steam turbine machinery. A large yacht so fitted would be completed this autumn, while the destroyer *Eden* and the third-class cruiser *Amethyst* would be completed in 1903. Within the last few weeks orders for two turbine cross-channel boats of about 8,000 H.P. had been placed with William Denny & Bros., one of them being for the Dover-Calais service. The total aggregate horsepower of the above vessels was 82,900 indicated. Considering

the question of fuel economy of marine turbine machinery, the author said that in the *Turbinia* and the *Viper* the coal burnt compared favorably at high powers. At cruising speeds the consumption was not excessive considering the size of the engines in terms of the power developed. In the *Velox* additional small reciprocating engines had been fitted, which would give a high degree of economy at low speeds, so that a small quantity of coal burnt would be secured both at high and low speeds. The success of the Clyde passenger steamer *King Edward* led to another somewhat larger vessel, the *Queen Alexandra*, being built, and she was reported to have given entire satisfaction. The *King Edward* on one season's work ran ten more miles than a similar paddle-boat of about the same dimensions and speed with a coal consumption of 480 tons less. The author concluded by stating that the adoption of the steam turbine system in vessels of large size, such as Atlantic liners, cruisers and battleships, would be attended with greater proportional advantages than in the case of smaller vessels. The large turbines would be cheaper to build, would be lighter, and would occupy less space in proportion to power. The design of such large turbines presented no difficulties beyond those already surmounted, and the greater size permitted the adoption of important features for the further reduction of coal consumption.

In the discussion that followed, Prof. Hele-Shaw discussed the relative merits of parallel flow and radial flow for turbines, and referred to the courage and perseverance shown by C. A. Parsons in bringing his invention to a successful issue after many years of work, often carried out under most discouraging circumstances. The great majority of engineers, the speaker, he confessed, among the number, did not believe the author of the paper would get an economical result. The mechanical accuracy reached in these machines was also worthy of the greatest admiration. Practical men had said the turbine would not last, owing to wear in its bearings, etc., but experience negatived the assumptions of the practical man. A steam turbine had been tested at Elberfeld in competition with a Corliss engine, a type

eminently economical, and the result had shown the turbine to have a considerably higher economy.

The lecturer, in the course of his reply, said that with superheated steam still higher efficiencies would be obtained. The gain due to superheating was equal to about 1 per cent. saving in steam used for every increase of 10 degrees Fahrenheit in temperature. He had tested as high as 200 degrees superheat with 150 pounds per square inch pressure, but there was no reason why higher temperatures should not be reached. The reverse turbine had been used for lifts up to 700 feet head in New South Wales, working with the pumps in series on the same shaft. The efficiency of propellers was a difficult subject. In the *Turbinia* he made certain assumptions, and concluded that the efficiency of the propellers alone was about 65 per cent., and that the augmented resistance of the shafts and under-water fittings was about 10 per cent. The velocity of the tips of the blades in the *Queen Alexandra* was not greater than in third-class cruisers. The reversing of the motion of the vessel had to be done by a separate turbine, the blades being run *in vacuo* when not in use, so as to decrease resistance. Tests had been made with a steam turbine and a Sulzer engine. At three-quarters load the two were equal in economy. Above three-quarters load the turbine had the advantage; below that the reciprocating engine was best. But the turbine required less oil, the saving amounting in value to about 16 per cent. of the cost of the steam. In the Newcastle central station £5 a week was saved in oil as compared to the amount that would be required in ordinary engines.—"Marine Review and Marine Record."

HOLLOW FORGINGS.*

How New Methods Have Improved Heavy Forgings.

There are two ways of making a forging hollow. The ordinary way of getting rid of the center of a forging is simply to

* Extract from paper read by H. F. J. Porter before the Engine Builders' Association.

bore it out. After boring it is tempered, and thus the strength is restored which was taken away with the material that was in the center.

Another way of getting rid of the center of large forgings is to forge them hollow. A person who has not considered the subject carefully would naturally think that the first thing to do in making a hollow forging would be to cast a hollow ingot. There are various defects which occur in ingots, however, the most serious of which are "segregation" and "piping," and it is in the center and upper portions that those defects occur. If an ingot were to be cast hollow a solid core of fire brick or similar material would replace the center metal, and instead of one on the outside there would be two cooling surfaces, one on the outside and one around the core, and the position of the last cooling would be transferred to an annular ring midway between those surfaces where the "piping" and "segregation" would collect. This would not be satisfactory because the metal there is what must be depended upon for the strength of the hollow forging. It is necessary, therefore, to collect the "piping" and "segregation" in the center and at the top, where metal has been added to the original ingot for the purpose. Then, having cut off the top and bored out the center, the "piping" and "segregation" are entirely eliminated, and what is left is as sound and homogeneous a piece of steel as can be obtained.

After the hole has been bored in the ingot the next process is to reheat it, and, as before explained, this process is not as delicate a one as if the ingot were solid. The heat affects the center equally with the exterior, and the two expand together and the danger of cracking is not incurred. When the ingot is reheated a steel mandrel is put through its hollow center, and, subjecting the two to hydraulic pressure, the metal is forced down and out over the mandrel. Thus an internal anvil is practically inserted into the forging, and there is, therefore, really much less than one-half the amount of metal to work on than if the piece were solid.

When the work of shaping is completed the forging is reheated to the proper temperature and then either annealed in the usual

manner or plunged into a tempering bath of oil or brine to set the fine grain permanently that has been established by the reheating. A mild annealing follows, to relieve any surface strains that may have been occasioned by the rapid cooling.

Hollow forgings oil tempered and annealed are considered the best grade of forgings made, and any forgings made otherwise, although they may be suitable for the service to which they may be applied, cannot be looked upon in any other manner than as of an inferior grade.

That steel forgings of such high grade were being manufactured for commercial purposes in this country was first brought to the attention of manufacturers generally at the World's Fair in Chicago. Here were exhibited stationary-engine forgings which compared favorably with those sent over by European forges. The Ferris-wheel shaft, 45 feet long and 32 inches outside diameter, with a 16-inch hole through it, represented the largest shaft made up to that time. The soliciting of orders for such forgings, however, at once aroused the latent prejudice still existing against steel forgings, and the prices demanded, being somewhat in excess of those which wrought-iron or ordinary steel forgings could be obtained for, prevented at first the very rapid introduction of this product into the commercial field.

DIFFICULTIES ENCOUNTERED IN INTRODUCING HIGH-GRADE FORGINGS.

It hardly seemed necessary to explain to an engineer or any one authorized to purchase, and therefore presumably competent, that if he wanted material to sustain severe usage in the nature of alternating stresses, to which all forgings are subjected, he should select a material possessing a very high elastic limit. And yet it was not unusual to find that those very people preferred to use wrought iron for their engine crosshead and crank pins and shafts in perference to steel, because, as they said, "steel, being crystalline, is brittle and snaps off suddenly under such services as that under consideration, while iron, having fiber, is tougher and yields before breaking." Most of these men knew better, but had not given the subject sufficient thought, or they would have perceived that their statements were not consistent. They

said that the steel connecting rods they had tried had broken off short without any warning, while rods made of wrought iron had simply bent up, and, after having been straightened out, were replaced as good as new.

These people did not stop to think that a steel rod that broke off short had done so at its ultimate strength or under a stress of from 80,000 to 90,000 pounds per square inch, whereas the iron rod which had doubled up had done so at its yielding point of 25,000 to 30,000 pounds per square inch. In other words, their engines with wrought-iron rods were failing all over the country under loads about one-third what they were standing up to when supplied with steel rods, yet the men were blaming the steel for helping them out of their troubles.

Then, again, they complained that steel shafts and crank pins heated up, while wrought iron ran cool. When it was proved to them that laboratory experiments showed the co-efficient of friction of these metals to be the same, and that any difference in heating was caused by local circumstances, such as poor lubrication, excessive pressure, etc., they said they did not care for laboratory experiments. They had an engine in one place with a steel shaft that never would run cool, while another with a wrought-iron shaft had never given any trouble, and they were passing judgment on their own experience. Persistent exposure of these fallacies gradually brought about a change in sentiment.

"Cold Crystallization" does not Occur.

It took a long time to persuade people who had seen broken forgings which showed a coarse crystalline section that the metal had not crystallized from shock or vibration in service, but had been forged in such a manner that the crystalline condition of the ingot from which the forging had been made had not been changed by the forging process or by subsequent heat treatment. And these are the people even now who consider themselves conservative, who would rather have their forgings made of a mild steel which is weak than of a higher carbon steel which is strong, simply because the old ideas are not yet eradicated from their minds. Tests were made at the Government

testing bureau at Watertown by rapidly bending bars forward and backward within their elastic limit with the following results, and these have given engineers an idea of the comparative endurance of wrought iron, steel and nickel-steel, in such service as that to which crank pins, shafts, etc., are subject:

TESTS OF STEEL UNDER REPEATED STRESSES.

Under a Fiber Stress of 40,000 Pounds Per Square Inch.

	Alternations of Stress.
Wrought iron breaks after	50,000
.15 per cent. carbon steel breaks after	170,000
.25 " " " " " "	229,000
.35 " " " " " "	317,000
.45 " " " " " "	976,000
3½ " " nickel-steel carbon .25 to .30 per cent.	1,850,000
4½ " " " " .25 " .30 " "	2,360,000
5½ " " " " .25 " .30 " "	4,370,000

Engineers and those whose duties it is to purchase forgings have been led to see that they should specify definitely the strength that they wish the material to possess, and then to follow up the specifications by inspection to insure receiving what has been ordered.

REQUIREMENTS AND GUARANTEES FOR STEEL FORGINGS.

Class of steel forging.		Tensile strength, lbs. per sq. in.	Elastic limit, lbs. per sq. in.	Elongation. Per cent.	Contraction of area. Per cent.
Nickel-steel.	(1)	95,000	65,000	21.00	50.00
Oil tempered.	(2)	90,000	60,000	22.00	50.00
	(3)	85,000	55,000	24.00	45.00
Nickel-steel, annealed.	(4)	80,000	50,000	25.00	45.00
	(5)	80,000	45,000	25.00	45.00
	(6)	80,000	45,000	24.00	40.00
Carbon steel, oil tempered.	(7)	90,000	55,000	20.00	45.00
	(8)	85,000	50,000	22.00	45.00
	(9)	80,000	45,000	23.00	40.00
Carbon steel, annealed.	(10)	80,000	40,000	22.00	35.00
	(11)	75,000	37,500	23.00	35.00
	(12)	70,000	35,000	24.00	30.00

During the past few years a series of specifications has been drawn up and adopted by the International Association for Testing Materials, which is composed of engineers, manufacturers,

companies, associations, societies, and any individual or organization interested in obtaining standards. The standard specifications for forgings are herewith given for convenient reference, and the physical properties mentioned are obtained from test bars drilled from a full-sized prolongation forged to one end of the forging, these test bars being of the United States Navy standard size, $\frac{1}{2}$ inch diameter and 2 inches long between gauge marks.

Dimensions of solid and hollow forgings in which the physical qualities mentioned in the above table are guaranteed:

(1) Solid or hollow forgings, no diameter or thickness of section to exceed 3 inches.

(2) Solid forgings of rectangular sections not exceeding 6 inches in thickness, or hollow forgings, the walls of which do not exceed 6 inches in thickness.

(3) Solid forgings of rectangular sections not exceeding 10 inches in thickness, the walls of which do not exceed 10 inches in thickness.

(4) Solid or hollow forgings, no diameter or thickness of section to exceed 10 inches.

(5) Solid forgings, no diameter to exceed 20 inches or thickness of section 15 inches.

(6) Solid forgings over 20 inches diameter.

(7) Solid or hollow forgings, no diameter or thickness of section to exceed 3 inches.

(8) Solid forgings or rectangular sections not exceeding 6 inches in thickness, or hollow forgings, walls of which do not exceed 6 inches in thickness.

(9) Solid forgings of rectangular sections not exceeding 10 inches thickness, or hollow forgings, walls of which do not exceed 10 inches in thickness.

(10) Solid or hollow forgings, no diameter or thickness of section to exceed 10 inches.

(11) Solid forgings, no diameter to exceed 20 inches or thickness of section 15 inches.

(12) Solid forgings over 20 inches in diameter.—"Machinery."

BURNING BRASS TIPS ON CAST-IRON PROPELLERS.

A method of repairing cast-iron propeller wheels is in vogue at Mort's Dock & Engineering Co.'s foundry, Sidney, N. S. W., which is said to be practically unknown in Europe and America. It is the fusion of gun-metal tips to cast-iron propeller blades by the "burning-on" process. On account of cost, cast-iron propellers are used to a large extent although they are, of course, much inferior to bronze in point of durability. The "tips," the portion 12 to 18 inches from the ends of the blades, are likely to be broken by striking floating debris, hidden rocks, wharf projections, "racing," etc., but the greatest source of damage in the case of steel and iron vessels is corrosion due to galvanic action.

When a propeller blade is broken, the usual method of repair is to replace it with a new one, but it sometimes happens that a ship cannot be detained in port long enough to allow a new blade to be made, and in that case a new tip is "burned on," which can be done in a few hours. The blade to be repaired is taken to a drilling machine and drilled across with holes about one-half inch apart, so that the bad part may be easily broken off. It is then taken into the iron foundry, bedded in the floor, and a cope rammed up over the portion that is to be renewed. The mold is then parted, finished, dried, closed and cast with gun metal in place of the cast-iron tip which has been broken off. The gun metal having been cast against the cast-iron blade, it has now to be "burned" to it.

The cope is thrown off while the casting is hot, and an "open" burn laid right across where the brass and iron join. It is then burned with iron, care being taken that the metal from the ladle falls directly onto the iron part of the blade so as to cut into it without washing away too much of the brass. If attention is given to the center, or thickest part of the blade, in the process of burning, one can always make sure of a satisfactory joint. The proper way is to use a feeding rod as a guide, working it along the joint gradually as the iron dissolves. After the burn is thoroughly cooled it is trimmed off, and the blade sent to the ship. Although a blade treated in this way presents a somewhat piebald appearance—owing to the light and shade of brass and

iron—there is nothing weak about it. All sorts of mechanical tests have been made in order to separate the brass and iron, without success. The bronze tip is not, of course, affected by corrosion, so the repaired blade is practically better than the original.—" Machinery."

MISCELLANEOUS NOTES.

Oil Fuel—Extract from 1902 Report of the Engineer-in-Chief of the Navy.—There is quite a widespread misconception regarding the part that the steam which is used for atomizing purposes plays in effecting combustion. It is supposed by many that after atomizing the oil the steam is decomposed and that the hydrogen and carbon are again united, thus producing heat and adding to the heat value of the fuel. While it may be true that the presence of steam may change the character and sequence of the chemical reaction, and result in the production of a higher temperature at some part of the flame, such an advantage will be offset by lower temperatures elsewhere between the grate and the base of the stack. All steam that enters the furnace will, if combustion is complete, pass up the stack as steam, also carrying with it a certain quantity of waste heat. The amount of this waste heat will depend upon the amount of steam and its temperature at entrance of the furnace. The quantity of available heat, measured in thermal units, is undoubtedly diminished by the introduction of steam. In an efficient boiler it is quantity of heat rather than intensity that is wanted. For many manufacturing purposes intensity of heat may be of primary importance, but in a marine steam generator a local intense heat is objectionable on other grounds than those of economy, viz: its liability to cause leaky tubes and seams from the unequal expansion of heating surfaces.

The following information has undoubtedly been secured:

(a) That oil can be burned in a very uniform manner.

(b) That the evaporative efficiency of nearly every kind of oil per pound of combustible is probably the same. While the crude oil may be rich in hydrocarbons, it also contains sulphur, so that,

after refining, the distilled oil has probably the same calorific value as the crude product.

(c) That a marine steam generator can be forced to even as high a degree with oil as with coal.

(d) That up to the present time no ill effects have been shown upon the boiler.

(e) That the firemen are disposed to favor oil, and therefore no impediment will be met in this respect.

(f) That the air requisite for combustion should be heated, if possible, before entering the furnace. Such action undoubtedly assists the gasification of the oil product.

(g) That the oil should be heated so that it could be atomized more readily.

(h) That when using steam higher pressures are undoubtedly more advantageous than lower pressures for atomizing the oil.

(i) That under heavy forced-draft conditions, and particularly when steam is used, the board has not yet fou nd it possible to prevent smoke from issuing from the stack, although all connected with the test made special efforts to secure complete combustion. Particularly for naval purposes is it desirable that the smoke nuisance be eradicated in order that the presence of a war ship might not be detected from this cause. As there has been a tendency of late years to force the boilers of industrial plants, the inability to prevent the smoke nuisance under forced-draft conditions may have an important influence upon the increased use of liquid fuel.

(j) That the consumption of liquid fuel can not probably be forced to as great an extent with steam as the atomizing agent as when compressed air is used for this purpose. This is probably due to the fact that the air used for atomizing purposes, after entering the furnace, supplies oxygen for the combustible, while in the case of steam the rarefied vapor simply displaces air that is needed to complete combustion.

(k) That the efficiency of oil-fuel plants will be greatly dependent upon the general character of the installation of auxiliaries and fittings, and therefore the work should only be entrusted to those who have given careful study to the matter,

and who have had extended experience in burning the crude product. The form of the burner will play a very small part in increasing the use of crude petroleum. The method and character of installation will count for much, but, where burners are simple in design and are constructed in accordance with scientific principles, there will be very little difference in their efficiency. Consumers should principally look out that they do not purchase appliances that have been untried and have been designed by persons who have had but limited experience in operating oil devices.

HOHENSTEIN BOILER.—EXTRACT FROM 1902 REPORT OF ENGINEER-IN-CHIEF OF THE NAVY.—With an improved casing and a large front drum for the boiler, the series of experiments conducted indicate that this boiler is a satisfactory steam generator for the naval service. The board therefore recommends that the Hohenstein boiler be given a place on the very limited list of straight-tube water-tube boilers of American design that have been found suitable for naval purposes.

The board believes that the important question of selecting an approved water-tube boiler for naval purposes will be finally settled by a process of selection from types installed on board ship, and subjected for several years to the stress of service conditions. In order, therefore, to assist in discovering an approved type that will meet the requirements of the Navy, the board recommends the use of the Hohenstein boiler on an American war ship, perferably one requiring a large installation.

NINE TORPEDO-BOAT DESTROYERS were arranged for in the British Navy estimates for the current year, the orders for which have now been placed. Two vessels are to be built by each of the following firms: Laird, of Birkenhead; Palmer, of Jarrow-on-Tyne; Hawthorn, Leslie & Co., Newcastle-on-Tyne; and Yarrow, London; while the ninth boat will be constructed by Thornycroft, of London. One of the Hawthorn-Leslie's two boats will be fitted with Parsons' steam turbine machinery, similar to that in the torpedo-boat destroyer *Velox*. The new de-

stroyers will be larger than those now in the service, and will have a large forecastle, which will greatly improve their seaworthiness. They will be of heavier scantlings, and the guaranteed speed is to be 25½ knots.

FOR LINING BEARINGS, crank-pin bushes and other parts, exclusive of crosshead bushes, the following alloy has, in hard ocean steaming, been found, after extended experience, to give good results: Twelve parts tin, one part copper, one part antimony, mixed in the following way: six parts tin alloyed with one part antimony, and six parts tin with one of copper, and the two mixed together. For lining crosshead brasses the following harder alloy has been found to give good results: 85 per cent. tin, 5 per cent. copper and 10 per cent. antimony.

THE BRITISH ADMIRALTY has recently awarded the contract for a 16,500-ton battleship, to be equipped with 18,000-horsepower Niclausse boilers. This is the eighth ship of the English Navy for which these boilers have been specified in the past sixteen months, a fact which is significant in view of the recent *Minerva–Hyacinth* trials. The aggregate horsepower of Niclausse boilers in use or contracted for in the English Navy is now 114,000; in the United States Navy, 105,000.

THE LONDON "ENGINEER" remarks that "the *Surly* has been running some more trials with liquid fuel, and the results have been regarded as so valuable that they have been made 'strictly confidential,' lest the ordinary officer concerned should get to know, and by some incautious word help an inquisitive press to gain some inkling of results. We believe, however, that the discovery has been made that possibly France, Italy, Russia and Germany have, after all, fitted their ships for liquid fuel during the last ten years with some other object than trying to induce this country to adopt something useless. This is a serious matter. The pity is that the Admiralty never thought of making our adoption of Bellevilles confidential. What a lot of trouble that would have saved."

IT IS REPORTED that the Admiralty intend to pursue their experiments with submarines further, and will order some additional new boats of the *Holland* type, which will differ very largely from the first boat of the flotilla now in the water. Since this boat was launched mechanical alterations have been continually introduced into the other boats as the trials with *No. 1* boat suggested, and internally the machinery has been altered from the original in almost every respect.—"London Engineer."

THE PROPELLER PROBLEM, alike as regards propulsive efficiency and vibration, is one of the difficulties of the naval tests now being undertaken by the *Chateaurenault*, a French protective-deck cruiser, which has just concluded special propeller trials. She is a vessel of 8,018 tons displacement, with Express water-tube boilers and three sets of engines, which collectively develop over 23 knots. Originally, her three propellers had each three blades. The central screw while on trial got one of its blades broken, and when a new propeller was being made, it was decided to make it with four blades. The result was to greatly reduce the vibration, which had formerly been excessive. With the new propeller the trials also showed higher efficiency, because over the short measured course, with the wind, the speed was 24.19 knots, and against the wind, 23.88 knots, giving the high mean of 24 knots. The result was regarded as highly satisfactory. In most of our ships, three-bladed propellers are used. With our big cruisers of the *Good Hope* class it has been experienced that with a following sea there in not only difficulty in steering, the vessel "yawing" or zigzagging in her course badly, but vibration at some points is set up. The *Good Hope* is, therefore, when commissioned, to go to sea when the weather is rough, to test with vibrometers the effect of following seas on the ship's structure, and particularly upon the compass. —Engineers' Gazette."

GERMANY HAS THE FASTEST merchant cruisers, with three of 23 knots and two of 22 knots; the United States coming next, with two of 22 and two of 20. British rank third, with two

(Cunarders) of 21 and two (White Star) of 20 knots. France and Russia have each two of 20 knots. The general speed is indicated by the fact that, of merchant steamers doing 15 knots or over, France has twenty-eight, Great Britian twenty-six, Germany fifteen, Russia nine and the United States seven.

REPORTS FROM FRANCE concerning recent trials of that government's submarine boats have demonstrated their efficiency. France has now sixteen submarine boats and thirty-six are being built. Four submarine boats traveled by their own power from Cherbourg to Brest to attack the coast defense ship *Fulminant*. The latter kept moving about the harbor to avoid them, and the crew maintained the sharpest watch they could for signs of the submarines. Nevertheless, the first indication of the presence of the submarines was obtained when all four came to the surface near the *Fulminant*. They had entered the harbor and surrounded the ship without having been perceived, and would surely have destroyed her in case of war. At Cherbourg a blockade of the port was established by submarine boats, and a squadron attempted to pass through it without being torpedoed by the submarines. The contest ended in the victory of the latter. In one case the submarine *Français* hit the battleship *Bouvines* with a torpedo, dived under her, came up on the other side and torpedoed her again. During the maneuvers the sea was high and the weather stormy.

IT IS REPORTED that the turbine steamer which the directors of the South-Eastern and Chatham Railway have ordered from William Denny and Brothers, of Dumbarton, will introduce an entirely new type of vessel into the channel service between Dover and Calais. Three turbines will be used, worked by three independent lines of shafting. The center shaft has one propeller, while each of the side shafts is to work two propellers. In maneuvering, the center shaft will run free, those at the side taking the place of ordinary twin screws. The builders have undertaken that the new steamer shall have an average sea speed of 21 knots.—"London Engineer."

ACCORDING TO REPORTS from Yokohama, the Japanese Minister of Marine has decided upon his new scheme of naval expanson. It is proposed to build four battleships, six first-class cruisers, and various smaller craft. The battleships will be built in England; the cruisers in England, France and Germany, and the remainder of the new fleet in Japan. This program embraces the construction of 120,000 tons, extending over a period of six years. The scheme will involve an annual expenditure of about 2,000,000 pounds sterling.—London "Engineer."

THE BRITISH ADMIRALITY have issued an important order affecting the torpedo fleet. All vessels below 30-knot destroyers are to have their armament changed; 27-knot destroyers are to carry in future only one torpedo tube instead of two, and first-class torpedo boats to carry only three torpedo tubes instead of five. This is to enable the craft to move with greater celerity when attacking the hostile ships at night.

SHIPS.

UNITED STATES.

Opening of Bids for New Battleships.—Bids for the construction of the battleship *Louisiana*, authorized by the last naval appropriation act, were opened at the Navy Department on October 1. The Newport News Shipbuilding Company bid $3,990,000, and this bid was accepted, the vessel to be completed in forty-one months. The other bids were: William Cramp & Sons, $4,114,500, in forty-two months; Union Iron Works of San Francisco, $4,150,000, in forty-two months; New York Shipbuilding Company, $4,040,000, in forty months, and the Fore River Shipbuilding Company, $4,087,000, in forty months. By law, firms on the Pacific coast are allowed 4 per cent. excess over the lowest bid, which, if applied to the bid of the Union Iron Works, would bring their bid down to $3,990,400, only $400 in excess of that submitted by the Newport News Company. The cost of the construction of this vessel is of the greatest importance in view of the fact that under the law authorizing the two battleships, the *Connecticut*, which is to be built at a Government navy yard, and the *Louisiana*, a comparison in the cost of the two ships will be made for future reference in the matter of determining the advisability of building vessels at Government yards. The *Louisiana* and the *Connecticut* are to be the largest and most powerful battleships in the Navy.

Des Moines.—This protected cruiser was launched from the yard of the Fore River Ship and Engine Co., Quincy, Mass., on September 20.

The principal dimensions of the *Des Moines* are as follows: Length on water line, 292 feet; over-all length, 308 feet 9 inches; beam, molded, 43 feet 3¼ inches; beam (extreme), 44 feet; freeboard, forward, 20 feet; freeboard, aft, 18 feet 6 inches; free-

board, amidships, 15 feet 9 inches; corresponding displacement, 3,200 tons; speed required by contract, 16½ knots an hour.

She will have a bunker capacity of 700 tons of coal, which will enable her to steam 2,600 miles at full speed and 9,800 miles at a rate of 10 knots an hour.

The *Des Moines*' machinery consists of two four-cylinder triple-expansion engines, with high-pressure cylinders 18 inches in diameter, intermediate, 29 inches in diameter, and low-pressure, 35½ inches in diameter, with a common stroke of 30 inches. The *Des Moines*' boilers are constructed for a working pressure of 275 pounds per square inch. She has six Babcock & Wilcox boilers, with a total grate surface of about 300 square feet, and a total heating surface of 13,000 square feet. There will be two smoke pipes, the top of each being 70 feet above the grates. She will have two masts, the forward one being fitted for wireless telegraph purposes.

She will have in her main battery ten 5-inch, 50-caliber, breech-loading, rapid-fire guns, and in the secondary battery eight 6-pounder rapid-fire guns, two 1-pounder rapid-fire guns and four Colt machine guns.

Eight of her main guns will be mounted on the main deck in recessed ports, the four forward ones having a range from right forward to 60 degrees abaft the beam, and the four after ones from right aft to 60 degrees before the beam. The two remaining 5-inch guns will be mounted behind shields on the spar deck, one forward and one aft. Four 6-pounders will be mounted on the main deck, two forward and two amidships, and four more on the spar deck. The two 1-pounder guns will be mounted aft on the main deck, and the Colt machine guns on the top of the hammock berthing.

The watertight deck, covered with one-half inch plate, has been worked from stem to stern, the sides sloping down to three feet below the water line, and the midship portion rising 18 inches above the same. This is on the line of the berth deck for the greater part of the length, but toward the ends it slopes down. On top of the watertight deck, at the sides, a belt of obdurating material is worked, covering the water line for the en-

tire length of the ship. All of the propelling machinery, steering gear and magazines will be below the watertight deck. The vessel will have a sail area of 6,000 square feet.

The vessel will be equipped with searchlights, an electric signal system, and a complete installation of electric lights. The blowers supplying the ventilators, the deck winches and the turning engines for the main engines will be operated by electricity. She will carry a 30-foot steam cutter, a 20-foot launch, two 28-foot cutters, a 28-foot whaleboat gig, a 28-foot whaleboat and an 18-foot dinghy. The *Des Moines* will be fitted with a distilling plant, an ice machine and refrigerating room. Quarters will be provided for the following complement: One commanding officer, 12 wardroom officers, 10 junior officers, 4 warrant officers, 8 warrant machinists, 238 sailors and 25 marines, making a total crew of 298.

Goldsborough.—ACCIDENT TO MACHINERY.—On September 8, 1902, while running her one-hour trial, the engine speed was increased to 300 revolutions per minute, giving a speed of 27.8 knots by the old standardization curve, and 25.7 by the curve recently made.

About two and one-half minutes after the trial was declared to begin, the port engine was seriously wrecked by the breaking of the forward web of the after L.P. crank.

The breaking of the crank web was almost immediately followed by the following damage to the engine:

(a) Arm of No. 4 main bearing broken, forced down and a piece thrown violently against the engine-room bulkhead.

(b) Nos. 2, 3 and 5 main bearings forced down and badly sprung.

(c) After web of I.P. crank broken through.

(d) Two L.P. cylinders forced apart, the webs joining the same splitting through the bosses holding the vertical ties to main bearings.

(e) The H.P. and I.P. cylinders forced apart in the same manner.

(f) The forward L.P. valves broken.

(g) Rocker arm carrying forward L.P. valves bent.

(h) After L.P. valves damaged from having over-ridden and struck.

(i) Angle frames under engine warped and drawn together.

(j) Vertical engine ties and frames sprung.

(k) Forward L.P. valve stems sprung.

(l) Yoke carrying forward L.P. valve stem bent.

(m) Distance piece between forward L.P. valves bent.

(n) I.P. and both L.P. pistons driven down on piston rod about ¾ inch.

(o) Fore-and-aft and athwartship engine braces generally sprung.

Cause of the Accident.—An examination of the fracture of the forward L.P. crank shaft disclosed an old flaw in the forging of very considerable extent, with wavy lines parallel to the original flaw showing the progress of the fracture from time to time, the last lines being farther and farther apart as the fracture extended. The after web of I.P. also showed an old flaw of less extent. The other cracks may have been caused by the violent strains due to breaking of the shaft, but have the appearance of old flaws opened up and made more conspicuous by the strain to which they were subjected.

The various other damages are accounted for as follows: The L.P. crank web having carried away, the after L.P. engine was detached from the rest of the engine and left to drive the propeller alone, the other engines being closed down, the broken parts of the shaft and web over-riding, broke and forced down the main bearings, and parted the cylinders as described; the distortion of the bearings caused the breaking of the I.P. crank web; the displacement of the shaft caused over-travel of the L.P. valves and consequent damage to valves, stems, rocker arm, etc.

The engines, previously to the break-down, had been running smooth and all bearings perfectly cool, and were found perfectly cool immediately after.

That greater damage and no loss of life occurred was due to the presence of mind of the engine force and rapidity with which the throttle and stop valves were closed.

It is probable that other parts of the engine are strained, which is not apparent to the naked eye and will develop as the examination proceeds.

Stewart.—Had her standardization trial on October 22, and made a top speed of 29.7 knots over the measured mile, with an average of 335 revolutions per minute.

On the one-hour trial, following, she averaged a speed of 29.3 knots.

The machinery worked perfectly and a higher speed could have been easily obtained.

Trial of the Tuscarora.—The recent trial of the new revenue cutter *Tuscarora* was a complete success, the vessel developing a speed of 14¾ knots an hour, three-quarters of a knot in excess of her contract speed. Her engines, which are of the vertical-cylinder direct-acting type, made 193 revolutions per minute, but with this high speed but little vibration was noticed in the ship. The engines have a stroke of 27 inches and work under a pressure of 175 pounds of steam, and are of 1,200 horsepower. Two Scotch boilers of 12 feet 2½ inches interior diameter furnish the steam for the engines. The *Tuscarora*, when completed, will cost $157,000. She is 178 feet long, 30 feet beam, and is of 15-foot draught, and has a displacement of 660 tons. She is fitted out in modern style, and when completed will be sent to the Great Lakes for service on them.

Washington and Tennessee.—After reconsidering these armored cruisers, the Board on Construction have recommended that the horsepower be reduced to 23,000 in place of 25,000 as first designed. With this power, the engines will be the same as those for the armored cruisers of the *Pennsylvania* class, except two piston valves, 27 inches diameter, will be fitted to each L.P. cylinder. The sizes of all the engine auxiliaries and boilers will be reduced to those required for the *Pennsylvania* class, but the same types of machines and same arrangement of machinery will be preserved as laid out for the larger power.

Wyoming.—This monitor was tried on October 28 and 29 last, the standardizing trials being made on the first date. The highest speed realized was 12.37 knots with 2,800 I.H.P. and

216 revolutions. During the two hours' run, an average of 11.8 knots, speed was made with 201.3 revolutions and 2,452 I.H.P.

AUSTRIA.

Habsburg.—The trials of the Austrian battleship *Habsburg*, which recently took place at Pola, were interesting, inasmuch as the results obtained constitute, it is believed, a speed record for vessels of similar class and displacement. The *Habsburg* is the first vessel of the class completed by the Austrian Government, her sister ships, the *Arpad* and *Babenberg*, being now in course of construction. The following are the leading dimensions of the vessel, machinery and armament: Displacement, 8,340 tons; length between perpendiculars, 350 feet; beam, 65 feet; mean draught, 23 feet 3 inches; area of midships section at above draught, 1,324 square feet. The propelling machinery is of the twin-screw triple-expansion type, with inverted engines, having four cylinders arranged in manner similar to those fitted on board British first-class cruisers: High-pressure cylinders—diameter, 29.9 inches; mean pressure, 43.8 inches; low-pressure (2), 56.3 inches, with a uniform stroke of 37.4 inches; total cooling surface of the condensers, 15,000 square feet; estimated revolutions at full power, 135 per minute; propellers, four-blade type, 16 feet in diameter, having mean pitch of 16 feet. The steam-generating plant consists of sixteen Belleville boilers of the economizer type, similar to those recently fitted to the battleships and cruisers in our Navy, having a total heating surface of 30,300 square feet and grate area of 864 square feet; the working steam pressure at boilers is 300 pounds, and reduced by automatic valve to 250 pounds, at main engines. The total weight of machinery complete is 1,098 tons.

The vessel is protected by means of an armor belt for over 60 per cent. of its length, the spaces beyond being covered by heavy armored deck; total weight of armor carried, 2,250 tons. The artillery consists of three 24-centimeter Krupp guns 40 calibers in length, twelve 15-centimeter quick-firing guns 40 calibers in length, and twenty-four quick-firing guns of smaller caliber. The coal capacity is 800 tons, which at a speed of 12 knots pro-

vides for steaming a distance of 3,600 knots. The conditions of trial were that a mean power of at least 11,900 horsepower should be maintained and the vessel to be propelled at a mean speed of 18½ knots. The speed of the ship was to be taken during the full-power trial, over a carefully-measured course having a total length of 68 knots. The actual results obtained were as follows: Mean pressure at boilers, 285 pounds; mean pressure at high-pressure receivers, 224 pounds; mean revolutions, 141.47 per minute; vacuum, 26 inches; indicated horsepower, 14,942; mean speed for total distance of 68 knots, 19.62 knots. There was practically no vibration throughout the ship. The machinery and boilers worked with perfect regularity during the trial, no difficulties of any description being experienced. — London "Engineering."

ENGLAND.

King Alfred.—The armored cruiser *King Alfred* completed recently her official steam trials, and made some interesting record performances. She is one of four ships ordered about three years ago, and it is a fact worth noting in days of keen naval criticism that all four have gone through their severe steam tests without any trouble. The *King Alfred*, which was built, engined, armored and armed by Messrs. Vickers, Sons and Maxim, Limited, and in being thus completed as a fighting ship by one firm is exceptional, achieves the further distinction of being the fastest ship in the Navy, excluding only torpedo craft; for during her eight-hours' full-power trial she steamed at the rate of 23.465 knots as measured accurately on a deep-sea course. The nearest approach to this speed was by the sister-ship *Leviathan*, of 23.25 knots, and the *Drake* and *Good Hope*, of 23.05 knots. This very high speed for vessels of such exceptional fighting qualities is most satisfactory, for the *King Alfred*, of 500 feet in length and 14,100 tons displacement, carries coal to enable her to steam to Australia at 15 knots; she has 6-inch armor for a depth of 11 feet 6 inches along 396 feet of the length of her water line, while there is a continuation to the ram bow of increasing width, although of lessening thickness; and, finally, she has

two 9.2-inch breech-loaders, sixteen 6-inch quick-firers, and seventeen smaller guns.

The speed trials of these ships have, from first to last, been associated with the question of propeller efficiency. All four ships are alike in form, and similar propellers were adopted in each case. They are four bladed, 19 feet in diameter. The *Good Hope*, tried first, had her propellers set at a pitch of 22 feet 9 inches; the *Leviathan*, which followed, had her pitch increased to 23 feet 9 inches; the *Drake* to 24 feet—the maximum; and the *King Alfred* worked at 23 feet 9 inches. We give in Table I the speed results of all four ships. It would be a mistake to make any precise deduction as to propeller efficiency from the data, but in the case of the *King Alfred* there is a striking reduction in the percentage of slip at the full power—16.8 per cent., as compared with from 18 to 18.7 per cent. in the other ships; while at the lower powers the conditions seem more favorable than with the *Drake*. The possibilities of error in speed were less in the *King Alfred*, as she steamed over a new course, 8,678 feet in length, marked with posts, on Chesil Beach, a little to the east of Portland Bill, with quite 30 fathoms of water, and the minimum of tidal influence. At the Rame Head and Dodman course, where the other vessels were tried, cross-bearings—not always clearly distinguishable—were taken to mark the distance steamed on the chart. The power is higher for the revolutions made by the *King Alfred* than for the *Leviathan* or the *Good Hope*, although not so high as with the coarsened pitch of the *Drake*. This latter vessel is now being fitted at Portsmouth Dockyard with propellers of greatly increased surface. The Admiralty are to be commended for making these comparative trials, as the propeller problem is one of great interest.

In addition to a satisfactory propeller efficiency, the *King Alfred* has proved economical in coal consumption, and on the full-power trial the rate was lower than on the other ships. In all cases the coal required for running the many auxiliary engines is included without their power being reckoned. The *King Alfred* commenced her trial on Wednesday of last week with a thirty-hours' run at one-fifth power. The results, alike as regards

power and consumption, are set out in the first column Table II. The contract required 6,000 indicated horsepower, and the mean was 6,395, while the coal consumption was at the rate of 1.76 pounds per unit per hour. Four runs were made over the Chesil Beach course on the Wednesday, and the mean results are given in Table I. Immediately following this trial the vessel went on her thirty-hours' run at 22,500 indicated horsepower when the coal consumption was 1.82 pounds. Six runs were made on the Chesil Beach course and two runs between Rame Head and the Dodman, the speed on the former being 21.597 knots, and on the latter 21.98 knots, as shown in Table I. This is a shade more than was got by the *Leviathan* with practically the same pitch of propeller on the same trial over the same course. The mean results of the whole thirty-hours' run are given in the second column of Table II. The power averaged 22,605 indicated horsepower, with 106.7 revolutions.

On the full-power trial of eight hours' duration, the same

TABLE I.—MEAN RESULTS OF SPEED TRIALS OF H. M. SS. "KING ALFRED," "DRAKE," "LEVIATHAN" AND "GOOD HOPE."

Revolutions.	Indicated horsepower.	Speed, knots.	Percentage of slip.	Coal consumption, in lbs. per I.H.P.
		H. M. S. *King Alfred.*		
72.26	6,743	15.167	10.5	1.76
106.7	22,540	21.98	12	1.82
104.9	21,450	21.597	12.2	1.82
120.2	31,156	23.465	16.8	1.81
		H. M. S. *Drake.*		
72.3	6,937	15.43	11.8	1.72
105.9	23,103	22.08	13.9	1.78
116	30,557	23.05	18	1.83
		H. M. S. *Leviathan.*		
71.2	6,481	15.238	8.5	1.76
107.6	22,900	21.96	12.8	1.75
122.1	31,592	23.25	18.7	1.94
		H. M. S. *Good Hope.*		
77.5	7,953	15.91	8.4	1.87
109.1	22,467	22.10	9.6	1.83
126.2	31,088	23.05	18.5	1.92

TABLE II.—MEAN RESULTS OF POWER AND COAL-CONSUMPTION TRIALS OF H. M. S. "KING ALFRED."

	August 27 and 28. 30-hours' coal-consumption at ⅓ power.		August 29 and 30. 30-hours' coal-consumption at ¾ power.		September 2. 8-hours' full power.	
Date of trial						
Nature and duration of trial						
	Forward.	*Aft.*	*Forward.*	*Aft.*	*Forward.*	*Aft.*
Draught of water, feet and inches	26	26–11	26–3	26–5	26–1	26–1
Steam in boilers, pounds	220		250		283	
	Starboard.	*Port.*	*Starboard.*	*Port.*	*Starboard.*	*Port.*
Vacuum, inches	27.2	26.4	26.4	26	26.6	25
Revolutions per minute	70	70.5	106.6	106.8	118	119.6
Mean pressures, high, pounds	41	34.6	89.1	87	101.9	99.82
intermediate, pounds	14	14.1	33	35.8	39.2	42.9
low, forward, pounds	7.7	7.8	16.6	15.3	21.05	21.06
aft, pounds	6.8	7.2	16.98	16.4	21.98	21.96
Indicated horsepower, high	1,029	877	3,418	3,342	4,320	4,290
intermediate	938	954	3,377	3,670	4,436	4,923
low, forward	681	674	2,236	2,065	3,138	3,182
aft	601	641	2,285	2,212	3,276	3,328
Mean total indicated horsepower	3,249	3,146	11,316	11,289	15,170	15,723
collective indicated horsepower	6,395		22,605		30,893	
vacuum in smoke boxes	.25		.3		.47*	
Speed of vessel on deep-sea measured course, knots	15.167		21.597		23.465	
Coal consumption per indicated horsepower per hour, pounds	1.76		1.82		1.81	
Total water expended, tons	24		111½		39	

*Air pressure.

monotony of success was experienced as on the two previous runs, the engines and boilers working well. The canvas air shafts, used in all the later British naval ships, instead of cowls, as described in connection with the trial of the *Good Hope*, did not prove quite satisfactory. When well stayed and carefully trimmed to suit the wind, they may do well; but there is always the risk of the wind exercising such a pressure on the outside of the walls as to reduce the supply of air to the fans; as a matter of fact, the canvas cowls were taken down shortly after the *King Alfred's* full-power trial commenced, and the fans subsequently supplied all the air required. The mean power was 30,893 indicated horsepower, and a feature commented upon by the Government officials was the absence of noise by the engines.

TABLE III.—H. M. S. "KING ALFRED'S" TRIALS. MEAN RESULTS OF THREE RUNS OVER DEEP-SEA COURSE AT FULL POWER, SEPTEMBER 2, 1902.

	First run.		Second run.		Third run.	
	S.	P.	S.	P.	S.	P.
Vacuum, inches	27½	25	27½	25	27½	25
Revolutions per minute	119.6	121.5	119.2	122.2	118.1	120.5
Mean pres. in cylinders:						
High, pounds	102	100.4	101	101.2	99	100
Intermediate, pounds	38.6	43.3	40	44.5	39.7	43
Low, forward, pounds	21.2	21.4	20.8	21	20.2	20.2
Low, aft, pounds	22	22.3	21.2	21.6	21.5	21.2
Indicated horsepower:						
High	4,395	4,400	4,345	4,465	4,224	4,345
Intermediate	4,425	5,050	4,575	5,230	4,505	4,960
Low, forward	3,190	3,275	3,125	3,235	3,012	3,065
Low, aft	3,310	3,410	3,184	3,323	3,210	3,212
Total	15,320	16,135	15,229	16,253	14,951	15,582
Collective	31,455		31,482		30,533	
Speed, knots	23.766		23.53		23.04	

The coal consumption, as already noted, was 1.81 pounds. There was no trouble with the boilers; the stokers were inexperienced for the most part, and often acted on the prevalent view that the more coal the more steam, unaware of the importance of air as an element in combustion; otherwise the economy might have been still greater. But the fact that the loss of water

was only 1.65 tons of water per 1,000 horsepower hours on the thirty-hours' trial, and only 39 tons for the whole eight hours for the 30,893 indicated horsepower, proves that there was the minimum of wastage, or leakage.

At full power three runs were made over the Chesil Beach course to determine the speed of the ship. The results of the three runs are given in Table III. The mean revolutions were 120.2 per minute, the power 31,156 indicated horsepower, and mean of mean speed 23.465 knots, which, as has already been stated, makes this latest Vickers' ship the fastest in our Navy.—London "Engineering."

Bedford.—The new first-class armored cruiser *Bedford* has also gone through her official trials. The mean results of the first trial, with the engines working at low pressure, were as follows: Steam at engines, 238 pounds; in boilers, 255 pounds; vacuum, starboard, 26.8 inches; port, 26.3 inches; revolutions, starboard, 85; port, 84; I.H.P., starboard, 2,250; port, 2,272—total, 4,522; speed, 14.92 knots; coal consumption, 1.91 pounds per I.H.P. per hour. The mean results of the second trial at four-fifths power were: Steam, in boilers, 246 pounds; at engines, 222 pounds; vacuum, starboard, 25.6 inches; port, 27.1 inches; I.H.P., starboard, 7,952; port, 8,053—total, 16,005; air pressure, .26 of an inch; speed, 21.2 knots; coal consumption, 1.97 pounds per I.H.P. per hour.

At the eight-hours' full-speed trial the engines worked excellently throughout, but the estimated speed of 23 knots was not maintained, the mean being 22.7 knots. This result was the more disappointing because the engines were driven at considerably above the 22,000 I.H.P. calculated as the maximum when they were designed. The mean results were: Steam in boilers, 285 pounds; at engines, 228 pounds; air pressure in stokeholds, .32 inch; vacuum, starboard, 26 inches; port, 25.5 inches; revolutions, starboard, 149.2; port, 101; I.H.P., starboard, 11,286; port, 11,171—total 22,457; coal consumption, 2.12 pounds per I.H.P.

Having failed to realize the estimated speed on her steam trials, the *Bedford* is to be fitted with propellers having blades of a

larger size than those with which she is now supplied. The other vessels of the same class now in course of construction are to be similarly fitted before they leave the contractors' works.

The next vessel of the class to undergo her trials will be the *Monmouth*, now at the works of the London and Glasgow Shipbuilding Company. The trials will take place off Plymouth.

Berwick.—The first-class armored cruiser *Berwick*, of the well-known County class, has been launched. The figures generally descriptive of each of these vessels are: Length between perpendiculars, 440 feet; breadth, molded, 66 feet; displacement, 9,800 tons; indicated horsepower, 22,000; boiler pressure, 300 pounds; normal coal capacity, 800 tons; and speed, 23 knots. The vessels have side protection extending over a length of 350 feet from the stem to the armor bulkhead, the latter being 3 inches thick. The side armor is of specially hardened steel of three thicknesses—4½ inches, 3 inches and 2 inches. The armament consists of two twin 6-inch guns in barbettes—one forward and one aft—four 6-inch guns on the upper deck, and four 6-inch guns on the main deck, two 6-inch guns in midship casemates on the main deck, eight 12-pounder 12-cwt. guns, and two 12-pounder 8-cwt. guns, with an auxiliary armament of three 3-pounder and eight Maxim guns.

Donegal.—This armored cruiser, 440 by 66.2 feet, was launched September 4. The vessel has side protection extending over a length of about 350 feet from the stem to the armor bulkhead, which is 3 inches thick. The side armor is of specially-hardened steel of three thicknesses—4⅛, 3 and 2 inches, the 4⅛-inch armor extending from the armor bulkhead forward for a distance of about 240 feet, and the 3-inch armor for a distance of about 40 feet. Between this and the stem there is 2-inch nickel-steel armor. The protective deck proper extends from stem to stern, and ranges in thickness from three-fourths inch within the range of side armor to 2 inches outside. This deck is worked at the lower edge of the armor, and protects the vitals of the ship. Another deck, 1¼ to 1 inch in thickness, forms a crown over the side armor and armor bulkhead, etc. The general construction is similar to that usually adopted in

the service, the vessel being extensively sub-divided into numerous watertight compartments. The coal bunkers range along the sides of the machinery compartments both below and above the lower deck, and are provided with the usual fittings for rapidly handling and distributing the coals. The vessel's normal capacity is about 800 tons, but this can be doubled if necessary, ample space being allotted for this essential requirement.

The armament consists of two twin 6-inch guns in barbettes, one forward and one aft, inclosed in gun house with specially-armored inclined shields. These guns are served through armored trunks from the magazines and shell rooms. The barbette walls are 4 inches thick, and well supported by the general structure. Four 6-inch guns in casemates on the upper deck and four 6-inch guns in casemates on the main deck forward and aft, together with the twin guns, give fore-and-aft fire at a high range. Two 6-inch guns in midship casemates secure a heavy broadside fire. The fronts of the casemates are 4 inches thick of hard steel, with the rear plates 2 inches in thickness. Eight 12-pounder 12-cwt. guns and two 12-pounder 8-cwt. field and boat guns are distributed at suitable positions, with an auxiliary armament of three 3-pounder and eight Maxim guns. At the fore end of the vessel is provided a steel conning tower of 10 inches in thickness, with a communicating tube to protect the gear for controlling operations throughout the ship. A navigating bridge with the usual appliances is fitted forward.

The complement of the ship is about 700 officers and men, and the most ample provision has been made for their accommodation. An electric installation is arranged throughout the vessel on the double-wired system, while six powerful searchlights are fitted—two on the forward bridge, two on the shelter deck aft, and one on each mast on a platform of great elevation. The vessel will have three funnels and two masts. The propelling machinery consists of two sets of triple-expansion engines, fitted in two watertight compartments, each set having four inverted cylinders working on four cranks. Each high-pressure cylinder is 37 inches diameter, each intermediate 60 inches, and each of the low-pressure cylinders 69 inches diameter, all adapted for a

stroke of 3.5 feet. The high-pressure and intermediate-pressure cylinders are each fitted with a piston valve, and each low-pressure cylinder with a double-ported slide valve with a relieving ring at the back, all the valves being worked by the usual double-eccentric and link-motion gear. The reversing is effected by means of a double-cylinder steam engine, with gear of the all-round type, hand gear also being fitted. The crank, thrust and propeller shafting is of forged steel and hollow. Each of the propellers has a boss of gun metal fitted with three adjustable blades of manganese bronze.

The main condensers will be placed at the back of the engines, and are of cast brass, of oval form, fitted with brass tubes, the condensing water being supplied by four centrifugal pumps of gun metal, each fitted with an independent engine. The feed, bilge, and hot-well engines are all independent and separate from the main engines, steam for these and all other auxiliary machinery being supplied by a special range of steam pipes. The auxiliary exhaust steam will be arranged to discharge to the auxiliary condensers, the atmosphere and the low-pressure receivers and will also be utilized for working the evaporators. There are two auxiliary condensers, each fitted with a circulating pump and a small air pump. The vessel will be fitted with the usual auxiliary machinery—a complete distilling plant to supply fresh water to the boilers and for drinking purposes; four sets of engines and dynamos for producing the necessary current for electric lighting; two double-cylinder direct-acting engines, with the necessary gear for steering purposes; two complete sets of air-compressing engines and pumps, with the necessary air reservoirs and columns for charging torpedoes; and one ice-making machine of the cold-air type, including ice-forming chamber and a pump for circulating water in the air cooler. Steam will be supplied by an installation of thirty-one water-tube boilers and economizers, all of the latest Belleville type. The boilers will be arranged in three groups, each group fitted in a water-tight compartment. They are designed to work at a pressure of 300 pounds. Blower engines will be fitted in each boiler room to supply air to furnaces and combustion chambers,

and the necessary air for the stokehold ventilation will be supplied by large fans. Fans will also be fitted for the engine-room and ship ventilation.—The "Steamship."

Drake.—The first-class armored cruiser *Drake* has completed the series of progressive trials with experimental propellers with marked success, and is now the fastest large cruiser afloat. Three series were run on the measured mile in Stokes Bay, and four on the deep-sea course in Chesil Reach. Each series comprised four runs—two with and two against the tide—and the following figures show the means of each series: 1,685 I.H.P., 9.52 knots speed; 4,014 I.H.P., 13.06 knots; 6,520 I.H.P., 15.41 knots; 9,872 I.H.P., 17.93 knots; 14,801 I.H.P., 20.03 knots; 22,534 I.HP., 22.16 knots; 31,409 I.H.P., 24.11 knots. Her highest speed, with a 4-knot tide, was 24.96 knots. Throughout the trials she drew 26 feet 1½ inches forward and aft.

Exmouth.—The new first-class battleship *Exmouth* has completed her steam trials successfully. At the thirty-hours' four-fifths power the results were: Vacuum, 27.6 starboard, 27 port; I.H.P., 6,934 starboard, 6,840 port—total, 13,774; revolutions per minute, 113.2 starboard, 112.8 port; speed, 18 knots; coal consumption per I.H.P. per hour, 1.95 pounds. At the eight-hours' full-speed trials the engines developed 18,346 I.H.P., giving a mean speed of 19.05 knots, with a coal consumption of 2.13 pounds per I.H.P. per hour.

Flora.—The *Flora*, cruiser, which has undergone an extensive refit at Devonport at a cost of £20,000 had a steam trial to test the efficiency of the repairs of her machinery, and it was shown that the vessel is capable of developing the same engine power and attaining the same speed as she registered when a new vessel, ten years ago. On her last trial, with the engines working at 130 revolutions and registering 7,425 indicated horsepower, the log recorded a mean speed of 18 knots. The maximum air pressure applied during the trial was only ½ inch.

Monmouth.—The *Monmouth*, cruiser, is to go through a special program of speed trials. The first will be at 17,500 indicated horsepower, to be followed by a trial at 22,000 horsepower. These trials will take place over the deep-sea course

between Rame Head and Dodman's Point, and on their completion the vessel will be steamed over the same course four times at each of the following speeds: 13, 17 and 19 knots. Before returning to Devonport, the *Monmouth* will be subjected to capstan, anchor and steering-engine trials.

Montagu.—A further trial of the steaming capabilities of the battleship *Montagu* was recently made off Plymouth. The previouss team trial was of thirty hours at three-fourths of her full power, and, although the engines worked smoothly at the required power, there was an enormous leakage of water from the boilers. It was consequently believed that the trial at 13,500 indicated horsepower would probably have to be repeated. The instructions, however, were for a sixteen-hours' continuous steam trial, eight of which were to be at full power. The course selected was between Dodman's and Rame Head. The results at first were fairly satisfactory, but as the hours wore on it became evident that, owing to leakage from the boilers, the horsepower expected of the machinery would not come up to expectations.

At the conclusion of eight hours' steaming it was decided not to proceed further with the speed trials that day. The average horsepower registered per hour for the eight hours had been not quite 17,700 (instead of 18,000), and the speed 18.37 knots. The speed, therefore, leaves nothing to complain of, and it is anticipated that she will be able to make 19 knots when the drawback due to leakage in the boilers is remedied. The steadiness of the ship, considering the high rate of propulsion, was eminently satisfactory, and the vibration was reduced to a minimum. The working of the engines was excellent, not a hitch occurring throughout the experiment. They were afterwards put through the crucial test of stopping and starting, with the very best results. In view of the nature of the steam trial, another will have to be made by the contractors. It will be a sixteen-hour trial, eight hours at full power, followed by eight hours at 14,500 I.H.P.

Niger.—The first-class torpedo-gunboat *Niger*, which has been fitted by Palmer's Shipbuilding Company, of Jarrow-on-Tyne,

with new engines and boilers of the Reed water-tube type, has also successfully completed her trials. At her thirty-hours' coal-consumption trial, which was run at one-fifth of the maximum power, the results were as follows: Draught of water forward, 8 feet 9 inches; aft, 10 feet 4½ inches; air pressure, .3 inch; pressure of steam at boilers, 216 pounds; at engines, 205 pounds; vacuum, starboard, 26.3 inches; port, 26.7 inches; revolutions, starboard, 229 per minute; port, 232; mean pressure in cylinders, starboard, high, 31.7; intermediate, 15.9; low, 6.3; port, high, 30.1; intermediate, 15.7; low, 6.1; I.H.P., starboard, high, 187; intermediate, 227; low, 218—total, 632; port, high, 180; intermediate, 230; low, 216—total, 626; total I.H.P., starboard and port, 1,258; coal consumption, 1.71 pounds per I.H.P. per hour; speed, 14.493 knots.

At her full-speed three-hours' forced-draft trial the results were as follows: Pressure of steam in boilers, 231 pounds; at engines, 219 pounds; air pressure, 2.1 inches; vacuum, starboard, 25.5 inches; port, 25 inches; revolutions, starboard, 376; port, 378 per minute; mean pressure in cylinders, starboard, high, 98.1; intermediate, 48.1; low, 18.9; port, high, 99.6; intermediate, 48.5; low, 17.9; I.H.P., starboard, high, 954; intermediate, 1,124; low, 1,073—total, 3,151; port, high, 970; intermediate, 1,139; low, 1,022—total, 3,131; total, starboard and port, 6,282 I.H.P. (being 282 in excess of the power required by the specification); speed, 20.5 knots. The former engines of the *Niger* were of 3,500 I.H.P., and her maximum speed, 18.7 knots.

No. 110.—Messrs. John I. Thornycroft and Co., Limited, Chiswick, launched from their works a first-class torpedo boat, which will be known as *No. 110*. This vessel is the second of the five torpedo boats ordered from this firm at the latter end of last year. The length is 166 feet; breadth, 17 feet 3 inches; speed, 25 knots, carrying a load of 42 tons. The engines are to be four-cylinder triple-compound, and the boilers are of the Thornycroft-Schulz type.

Torpedo Boats Nos. 52, 53 and 55, reboilering.—Torpedo boats *Nos. 52, 53* and *55* will have their locomotive boilers replaced by boilers of the water-tube type.

New Battleships.—The two new battleships to be laid down this year, one at Portsmouth Dockyard and the other at private works—various firms having already submitted tenders—are to be of the same type as the *King Edward VII;* but the most interesting feature at the moment is in connection with the boiler installation. As in the case of the six armored cruisers recently ordered, one-fifth of the boiler power will be on the old cylindrical-boiler system, water-tube boilers supplying four-fifths. This arrangement was adopted also in the *King Edward VII*, but in the two sister ships already under construction—the *Dominion* and *Commonwealth*—the boilers are all of the Babcock and Wilcox type. In one of the new ships the Niclausse boiler will be fitted in combination with Howden's cylindrical boilers, in the other Babcock and Wilcox boilers, with the tank boilers in closed stokeholds. The particulars of the installations for the three systems may be thus tabulated:

——	*Commonwealth* and *Dominion*.	New contract ship.	New dockyard ship.
No. and system :			
Water tube	16 Babcock and Wilcox.	18 Babcock and Wilcox.	18 Niclausse.
Cylindrical	...	3 closed stoke-hold cylindrical.	3 Howden. Cylindrical.
Heating surface, sq. ft. :			
Water tube	47,250	39,000	37,500
Cylindrical	...	8,100	8,100
Total	47,250	47,100	45,600
Grate area, sq. ft. :			
Water tube	1,400	1,120	1,150
Cylindrical	...	243	243
Total	1,400	1,363	1,393

The power to be developed is in each case 18,000 indicated horsepower, so that the ships may have a speed of 18½ knots when displacing 16,350 tons. The weight of machinery in the case of the *King Edward VII*, with all her boilers of the water-tube type, will be approximately 1,735 tons, while for the new contract ship it works out to 1,750 tons, and for the new dockyard ship 1,765 tons. The variation is entirely due to boilers, the machinery being the same; and in the case of the two new ships, where a combination is adopted, the difference against the dock-

yard ship is owing almost solely to the cylindrical boilers. The engines are to be of the triple-expansion type, with four cylinders and four cranks, the diameters being respectively 38 inches, 60 inches, 67 inches and 67 inches with a stroke of 48 inches. The working steam pressure is to be 210 pounds. The ships are to be 425 feet long, 78 feet beam, and the draught under normal conditions will be 26 feet 9 inches. The vessels will be most effectively protected with hardened armor equal in depth on the broadside to the height of three decks, instead of two decks, as in previous ships—from 5 feet below the water line to the level of the upper deck, in three strakes, 9 inches, 8 inches and 7 inches thick, and extending to the ram. With four 12-inch, four 9.2-inch and ten 6-inch guns, they will have a great offensive power. London "Engineering."

New Battleships' Names.—Two of the three new battleships are to be named the *Maori* and the *New Zealand.*

New Vessels.—DATES OF COMPLETION.—The following dates have been furnished to the Admiralty as fixing approximately the dates of completion of vessels now in course of construction: *Montagu*, line-of-battleship, March, 1903; *Queen*, line-of-battleship, March, 1904; *King Edward VII*, line-of-battleship, March, 1905; *Encounter*, cruiser, September, 1904. When the Navy estimates for the current year were framed it was impossible to give an approximate estimate of the total cost of the *King Edward VII;* but now that the details of construction are advanced, it looks as if she will cost £1,500,000. The largest sum ever previously provided for building a line-of-battleship for the Navy was £1,129,756, the estimated cost of the *Venerable* at Chatham; but the *King Edward VII* will be larger by 1,350 tons than the *Venerable.* The *Queen*, for which also no estimate could be decided on up to March last, is now expected to cost £1,085,000 before she is ready for commissioning. The *Montagu* is so far advanced that her cost is estimated at £1,082,877, while the *Encounter* will absorb £424.731. London "Engineering."

"Scouts" Contracts to be Placed.—Contracts for the four new "scouts" will shortly be placed. Each firm tendered to their own design, the speed of 25 knots on an eight-hours'

run being practically the only decided stipulation made in the invitation to submit designs. The Admiralty idea was that a vessel of from 700 to 900 tons displacement would suffice, but the designs sent in varied from about 1,700 tons up to 3,200 tons, on the assumption that a "scout" must be as capable of keeping the sea as the largest and heaviest warship, and at the same time attain her full speed under the most adverse conditions. The ship builders most experienced in naval design have pronounced in favor of the larger vessel. A 700-ton ship would certainly cost less than one four times the size, but small craft were not very successful in the case of the vessels of the *Rattlesnake* and *Sharpshooter* class. The new vessels will probably be about 370 feet long, with a displacement of about 2,800 tons, which, with engines of 17,000 I.H.P. and boilers of the Express small-tube type, should enable the speed of 25 knots to be realized under all conditions.—"Marine Review and Marine Record."

Triumph.—The *Triumph*, which is to be fitted out as a floating base for torpedo-boat destroyers, at Devonport, is to be furnished with three water-tube boilers of the Belleville type. These boilers will be used for the instruction of young stokers and engine-room artificers.

FRANCE.

Chateaurenault.—The first-class protected cruiser *Chateaurenault* has at last been passed definitely for service. She is not a triumph in the way of rapidity of construction, as she was laid down more than six years ago, and launched rather more than four years ago. It is a year since her trials first commenced, and, although in her last full-speed trial she attained the very high speed of 24 knots, it is considered extremely doubtful whether, under the actual conditions of service, she will ever attain anything like that speed, her sister ship the *Guichen* having notably failed to do so. During her latest full-speed trial of two hours' duration the mean speed of 24 knots was obtained with the engines making 130.7 revolutions, developing 24,300 I.H.P. The engines are reported to have worked well, and the excessive vibration, so noticeable on previous trials, seems to have been

reduced to a minimum. The middle engine has been fitted with a four-bladed screw in place of the original three-bladed one. —"R. U. S. I."

Amiral Gueydon.—The first-class armored cruiser *Amiral Gueydon* is so far advanced that she has made the first of her preliminary trials; only the central engine was used, and this, making 77 revolutions, worked satisfactorily; at full speed the engines should develop 19,500 I.H.P., giving a speed of 21 knots, steam being generated by twenty-eight Niclausse water-tube boilers in four groups. A trial was also at the same time made of her two 7.6-inch guns, which are carried in turrets, one forward and one aft, and of two of her 6.4-inch Q.F. guns, of which eight are carried in armored casemates; but, defects exhibiting themselves in the mountings of one of the 7.6-inch guns and in one of the 6.4-inch, the trial had to be discontinued.—"R. U. S. I."

Gueydon and Marseilles.—Two more mishaps of a serious nature are reported with regard to the two new first-class armored cruisers *Marseilles* and *Amiral Gueydon*, which had commenced their trials at Brest and Lorient respectively. At her last trial, with the engines making 114 revolutions, developing 14,000 I.H.P., the speed attained by the *Gueydon* was 18 knots; both engines and boilers worked unsatisfactorily, while, as was the case in the *Jeanne d'Arc* and *Chateaurenault*, the vibration was excessive, and when turning with the helm hard over the strain on the after part of the ship was so great that some of the plates were bent and rivets started to such an extent that a considerable amount of water found its way into one of the compartments; the ship has been docked, and it is estimated that the repairs will take quite a month. Now the report comes from Brest that at the recent trial of the *Marseilles*, with the engines only developing 10,000 I.H.P., and the ship making 15 knots, in turning with the helm over about 20 degrees, the same thing has happened. All these mishaps would seem to show that the French constructors have carried lightness of hull to a dangerous extent, or else that there is something radically wrong in the workmanship both in the Government and private yards.—"R. U. S. I."

Kleber.—The *Kleber*, just launched at Bordeaux, is one of three 7,700-ton cruisers, the others being the *Desaix* and *Dupleix*.

She has been a long time on the stocks, but this is due to the fact that she has been practically completed before being set afloat. That is to say, guns, armor, machinery and boilers were all on board when she was floated.

The ship is of special interest in that she represents an entirely novel type. It is one little loved in France, where she has been severely criticised as too weak for modern war. How she compares with other ships will be seen from the following table.

Name	*Kleber*.	*Bayan*.	"*E*"	*Esmeralda*.	*Garibaldi* class.
Nationality	French.	Russian.	Austrian.	Chilian.	Italian.
Where built	France.	France.	Austria.	Elswick.	Ansaldo.
Displacement, tons.	7,700	7,800	7,400	7,000	7,400
Length, feet	426½	443	384	436	344
Beam, feet	58½	55½	62	53	59
Draught (mean)	24½	##	21½	20½	23
Guns	8 6.4-inch.	2 8-inch.	2 9.4-inch.	2 8-inch.	1 10-inch.
	4 4-inch.	8 6-inch.	5 7.6-inch.	16 6-inch.	2 8-inch.
	10 3-pdrs.	20 3-inch.	4 6-inch.	8 3-inch.	14 6-inch.
	6 1-pdrs.	7 small.	8 2.7-inch.	9 6-pdrs.	2 3-inch.
	...	...	15 small.	2 3-pdrs.	10 6-pdrs.
	...	...	...	8 Maxims.	8 1-pdrs.
Torpedo tubes (submerged)	None.	2	2	2	None.
Torpedo tubes (above water)	2	3	None.	1	4
Boilers	Niclausse.	Belleville.	Yarrow.	Cylindrical.	Belleville and Niclausse.
I.H.P.	17,100	17,000	12,300	16,000	13,500
Extreme speed, kts.	21	21	21	22.25	20
Screws	3	2	2	...	2
Armor belt, inches	4-2	8-4	2-6½	6	4½-6
Proportion of belt length	Complete.	½	½	½	Complete.
Armor, lower deck side, inches	None.	3	8½	None.	5
Armor deck, ins.	2½	2	1½ and 3½	2	Thin.
On heavy guns	...	7-inch.	8-inch.	Nil.	6-inch.
On heavy guns (bases)	...	7-inch tubes.	5-inch.	4½-inch.	6-inch.
On secondary guns	4-inch.	3-inch.	5-inch.	Nil.	6-inch.
On secondary guns (bases)	4-inch.	3-inch.	8½-inch.	Nil.	6-inch.
Coal (normal), tons.	880	750	820	550	650
Coal (maxi.), tons	1,200 and oil.	1,100 and oil.	Uncertain.	1,350	1,200 and oil.

In this list the *Kleber* certainly does not look well. The 6.4-inch is only a 100-pounder, and therefore better than the 6-inch only in penetration. The difference in this is scarcely worth consideration.

If we commute the broadsides to the value of 12-pounders (6-inch = 4, 8-inch = 6, 10-inch or 9.4-inch = 8), the ships we have compared stand as follows: 1. *Esmeralda* = 59; 2. *Garibaldi* = 50; 3. "*E*" = 46; 4. *Bayan* = 38; 5. *Kleber* = 31.

Nor in armor protection is she much better; the relative merits being: 1. *Garibaldi;* 2. "*E;*" 3. *Bayan;* 4. *Kleber;* 5. *Esmeralda.*

In speed the ships stand: 1. *Esmeralda*, 22.25 (23 on trial); 2. *Kleber*, 21; 3. *Bayan*, 21; 4. "*E*," 21; 5. *Garibaldi*, 20.

As the *Garibaldi* takes 13,500 I.H.P. to do a knot less than the 12,300 estimated for the *Austrian*, this vessel, though of better speed lines, is hardly likely to be much swifter. In the *Garibaldi* "handiness" has been aimed at. The relative merits in this direction are: 1. *Garibaldi;* 2. "*E;*" 3. *Esmeralda;* 4. *Kleber;* 5. *Bayan.*

In coal supply, a vital thing for cruisers, the relative order with full bunkers is approximately very equal, and so need not be assessed. Taking the other figures, we find the order of general value works out as follows: 1. *Esmeralda*, 7,000 tons; 2. *Garibaldi*, 7,400 tons; 3. "*E*," 7,400 tons; 4. *Kleber*, 7,700 tons; 5. *Bayan*, 7,800 tons.

It is certainly curious that the ships should thus work out in inverse order to displacement. It is, of course, an arbitrary placing, and must not be taken as meaning too much. Still saving that the *Bayan* would find favor before the *Kleber*, this order is that in which probably the bulk of naval officers would select the ships for war use. Of course, by what one reads, the *Esmeralda*, with her unprotected guns, would be nowhere in the place for favor, but the drift of modern naval ideas tends to put her just where this list brings her.

Let us imagine her engaged against the *Kleber*. To begin with, she has cylindrical boilers, which, in the present stage of water tubes, is a probable advantage. Other things apart, the cylindrical boiler is easier to stoke, for it needs less skill. Skillful stokers are certain to be short in all navies in war time, and, skillful or not, stokers will weary. Deck hands can work the "tanks" well enough, but not water tubes. Therefore "tanks" have a war value peculiarly their own. Still, as the *Esmeralda* probably carries cylindrical only because water tubes had hardly "come in" when she was built, we may as well pass to the next point in her favor. She has speed. In a word, she can fight

the *Kleber* or not as she pleases. Suppose her to so please, her battery is so overwhelmingly more powerful that the *Kleber* might never get in a reply, and that applies to most of the other the ships in comparison.

It is not, indeed, easy to see the *Kleber's* use. Her belt is a good substitute for a protective deck, but if ships had only water-line hits to fear they would be in little danger in battle. She lacks the protection of the *Garibaldi* and "*E*," and, sound as her system of gun mounting may be, the rest of her would soon be a wreck. Presumably she is, like our *Diadems*, merely an "ordinary cruiser" of an inferior type, too weakly gunned to be dangerous.

Not, however, that the design is bad so far as the placing of the guns go. Badly as, in our experience, twin guns seem to work, there is a deal to be said for a non-distributed armament. The six broadside 6.4-inch will certainly take longer to disable as they are than if they were all distributed. Our objection is that they are too few, seeing how little armor there is, for they cannot afford that best of protection, a beating-down fire. We dislike, also, the 4-inch pieces, which seem to us to multiply calibers to no purpose, the more so as the 7.6-inch usually carried in French cruisers is dispensed with in the *Kleber* for the sake of simplicity in armament. Twelve 5.5-inch would have been an infinitely better battery than the eight 6.4-inch and four 4-inch actually carried.

It is worth noting, by the way, that the amidship guns of the *Kleber* are not placed to give an end-on fire. Very likely such a fire would have had a paper value only. Still, their position is anything but ideal, for, wrecked by shell fire, the superstructure in which they nest is likely to jam these amidship turrets very early in the action.—London "Engineer."

GERMANY.

Prinz Heinrich.—The new first-class armored cruiser *Prinz Heinrich* has successfully completed her trials. On the 9th May she carried out a six-hours' full-speed forced-draft trial, when the engines made 126.7 revolutions, developing 15,703 I.H.P.,

703 H.P. over the contract, giving a mean speed of 20 knots. On the 5th June the ship had a twenty-four-hours' coal-consumption trial with the engines developing 10,500 I.H.P., the result being as follows: Revolutions, 111.3; I.H.P., 10,355; air pressure, 10 millimeters (.39 inch); coal consumption, 0.868 kilogram (1.913 pounds per hour) per H.P.; mean speed, 18.1 knots.

The result of the trial trips was awaited with great interest, since this vessel represents an entirely new type not represented in the German Navy, and, as regards size and strength of armament and armor protection, stands between the first-class armored cruiser *Fürst Bismarck* and the second-class cruisers of the *Freya* class.

The construction of the *Prinz Heinrich* was commenced in December, 1898, at the Imperial Dockyard in Kiel, and has, therefore, taken a little over three years to complete. The vessel is 393.6 feet long and 64.3 feet beam, and, fully equipped, has a draught of 24 feet and a displacement of 8,930 tons. Like all other new large ships of the German Navy she has three screws driven by the like number of separately mounted four-cylinder engines with triple expansion. The maximum speed is calculated at 20.5 knots. She has a coal stowage of 950 tons at normal draught. The armament consists of two 24-centimeter (9½-inch), ten 15-centimeter (6-inch) and ten 8.8-centimeter (3½-inch) Q.F. guns, as well as ten 3.7-centimeter (1½-inch) machine guns. The two heavy guns are mounted in two revolving turrets forward and aft and have a free arc of fire of 270 degrees each. Of the ten guns of the secondary battery (6-inch caliber) six are placed in the casemate, three on each side, in such a manner that the two forward ones can also fire right ahead and the after ones right astern. The other four are mounted in single revolving turrets above the casemate. The two forward ones of these can also fire right ahead, and the two after ones right astern. The lighter guns (8.8 and 3.7-centimeter) are placed on the upper deck and on the superstructures in such positions that each single one has as large an arc of fire as possible. Of the 3.7-

centimeter (1½-inch) machine guns, some have been placed in the tops of the two fighting masts.

The torpedo armament consists of four tubes for 18-inch torpedoes, three of which (one bow and two broadside tubes) are submerged; only the stern tube, protected by the belt armor, lies above the water line. In the ships of the *Freya* class the stern tube is lacking.

As regards armor protection, the *Prinz Heinrich* differs from the vessels of the *Freya* class in having a water-line armor belt, which extends over the whole length of the ship and is 4 inches thick on the water line. The turrets of the heavy guns have an armor thickness of 6 inches, as against 4 inches in the case of the other aforementioned cruisers. Of equal thickness as with these, viz: 4 inches is the armor protection of the forward conning tower and of the 15-centimeter (6-inch) guns (casemate and turrets), but in the *Freya* class the casemate of the *Prinz Heinrich* is entirely lacking. The light guns only possess the protection, customary in the German Navy, of protective shields affixed to the carriage bodies proper. Naturally, all the ammunition shafts leading to the gun mounts are also armored.

The slightly arched protective deck, which in the case of the beltless vessels, *Freya*, etc., has a thickness of 4 inches, has with the *Prinz Heinrich* only a thickness of 2 inches, tapering to 1.5 inches.

The complement consists of 34 officers and 470 warrant officers and men.—"R. U. S. I."

River Gunboats.—Two river gunboats, constructed at Hamburg, have completed their trials, during which they made 11½ knots. They will be sent to Africa for river work. The form of the new German river gunboats for use in China has now been decided upon by the German Admiralty, and the first one ordered from the Schichau yards at Elbing. Her length is to be 188.64 feet; beam, 31.44 feet; draught, only 2 feet; displacement, 170 tons. Her two engines will be supplied with steam by Thornycroft boilers, and will work two propellers, giving her a speed of 13 knots. Her radius of action at 10 knots will be 1,000 miles. She will be built throughout of Siemens-Martin steel, and have

a protection of nickel-steel of 8 millimeters (nearly one-third of an inch) round her sides, and 12 millimeters (nearly half an inch) for her conning tower. She will be armed with one 3.45-inch, one 1.96-inch, and two machine guns. She will have one signal mast, one funnel, and a searchlight, and will carry three boats. Her complement will be fifty-three men.—" R. U. S. I."

ITALY.

Francesco Ferruccio.—The new first-class armored cruiser *Francesco Ferruccio* was successfully launched on the 23d April from the Royal Dockyard at Venice. She is a sister ship to the *Garibaldi* and *Varese* launched in 1899, and her dimensions are as follows: Length, 344 feet; beam, 59 feet 9 inches, with a displacement of 7,350 tons on a draught of 23 feet 4 inches. The armor protection consists of a complete water-line belt of hard steel, 6 inches thick amidships, but tapering to 3 inches at the extremities, and rising amidships to the height of the upper deck, forming a central battery 150 feet long, shut in fore and aft by 5-inch armor bulkheads; the turrets for the heavy guns, one at each end of the central battery, are also protected by 6-inch armor, and there is an armor deck 1.5 inches thick. All the armor is of nickel-steel, made at the Terni Works under a special system. The armament consists of a 10-inch gun in the fore turret, and two 8-inch guns in the after, with ten 6-inch Q.F. guns in the central battery, and four more on the superstructure deck, one at each corner of the battery; there are also sixteen small Q.F. guns and four submerged torpedo tubes. The ship is twin screwed, and the engines are to develop 13,500 I.H.P. at full speed, giving a speed of 20 knots, steam being provided by twenty-four water-tube boilers of the Niclausse type. The normal coal supply of the ship is 600 tons, but 1,200 tons can be carried.—" R. U. S. I."

Nembo.—The new torpedo-boat destroyer *Nembo*, launched last year from the yard of Messrs. Pattison at Naples, has completed her steam trials successfully. There are three others of the same class under construction, viz: the *Aquilone*, *Borea* and *Turbine*. Their dimensions are as follows: Length between per-

pendiculars, 208 feet; beam, 19.6 feet; draught at full load, 6.33 feet forward and 7.5 feet aft; displacement, 330 tons. The hull is of steel plates, galvanized (*i. e.*, zinc-coated), and is divided into eleven watertight compartments as follows: Beginning forward, the first is the collision department, containing water tanks and chain lockers; second, forward crew compartment; third, compartment for firemen; fourth, forward boiler compartment; fifth, after boiler compartment; sixth, engine compartment; seventh, petty officers' quarters and dynamo room; eighth, officers' quarters; ninth, machinists'; tenth, after crew compartment; eleventh, store room for provisions. The magazines and torpedo store rooms are in the lower parts of some of the compartments mentioned. The armament consists of: One 3-inch gun on a platform above the conning tower with an arc of fire of 300 degrees. Five 6-pounders: one aft, two each side. Two torpedo tubes on central-pivot mounts with arcs of train of about 90 degrees on each side. The engines are twin-screw, 4-cylinder, triple-expansion, designed to develop 6,000 I.H.P., and give a speed of 30 knots; three Thornycroft water-tube boilers, furnishing steam at 213 pounds per square inch. Coal capacity, 80 tons. She has completed her contract trials, and is now ready for service. With 80 tons of coal on board, the displacement is 360 tons, but the trials were made with nearly all weights removed.

On the progressive trials the mean results of four runs over a measured base were: Average time on course, 3 minutes 52 seconds; boiler pressure in pounds, 220; mean I.H.P., 5,346; mean speed, 30.038 knots; mean apparent slip of screws, 11.22 per cent. The mean draught on this trial was 5.43 feet, and the corresponding displacement, 252 tons. The full-speed trials took place on October 21st under the following conditions: Mean draught, 5.57 feet; corresponding displacement, 264 tons; duration of trial, three hours; boiler pressure, about 200 pounds; air pressure in fire rooms, 1.2 to 1.57 inches; mean I.H.P., 5,278; mean revolutions, 369.11; mean speed, 30.20 knots; mean apparent slip, 11.24 per cent. At the six-hour coal-consumption trial the displacement was 266 tons, corresponding to a mean draught of 5.6 feet. The boiler pressure was about 200 pounds;

speed, 25.12 knots; revolutions, 311.24; I.H.P., 3,314; apparent slip, 12.44 per cent. The draft was forced, the air pressure in the fire rooms being equal to about 1 inch of water. The coal consumption was 66.54 pounds per square foot of grate area per hour, and 1.95 pounds per I.H.P. The performance of the machinery during the trials was satisfactory.—" R. U. S. I."

Turbine.—This sister vessel to the *Nembo*, has also completed her trials successfully. On the coal-consumption trial, with the engines developing 3,257 I.H.P., a speed of 25.2 knots was maintained for six hours, at a coal consumption of .889 kilogram (1.95 pounds) per I.H.P. per hour; the number of revolutions was 313; slip, 12.6 per cent.; the pressure of steam at the boilers being 200 pounds, with an air pressure of 20 to 30 millimeters (.78 to 1.18 inches). At the three-hours' forced-draft trial the engines developed 5.306 I.H.P., giving a speed of 30.1 knots, with 369 revolutions, the slip being 11.3 per cent.; the pressure of steam at the boilers was 205 pounds, and the air pressure 70 to 80 millimeters (2.75 to 3.14 inches).—" R. U. S. I."

MEXICO.

Tampico and Vera Cruz.—The United States Ship Building Co., at its Crescent ship yard, Elizabethport, N. J., have launched the two gunboats, *Tampico* and *Vera Cruz*. They are for the Mexican Government and are also designed to act as troopships. The nearest approach to them in the American Navy is the gunboat *Machias*. Their principal dimensions are: Length over all, 201 feet 6 inches; length between perpendiculars, 190 feet; breadth, molded, 32 feet 10 inches; depth, 15 feet 8 inches; draught, fully loaded, 10 feet; displacement, 980 tons; speed, 16 knots. Their armament is to consist of four 4-inch rapid-fire guns, four 6-pounder rapid-fire guns and one torpedo tube. The hull is built of steel throughout and the vessels are fitted with cellular bottoms all fore-and-aft, with peak trimming tanks at either end. Designed with an elliptical stern, ram stem and raised poop and forecastle, the ships have a decidedly pleasing appearance, and with their shallow draught are well adapted for their work around the coast of Mexico. The problem of em-

bodying in one design the fighting qualities of a first-class gunboat and the conveniences absolutely necessary in a troopship have been readily met in these wonderful little craft. The following brief description will give some idea of their design and equipment.

Two pole masts are stepped, one of which is fitted with a searchlight platform, and both of which are fitted with booms for hoisting boats, coal, ammunition or stores. On the center of the poop deck a 4-inch rapid-fire gun is mounted, having a range of 120 degrees from aft to forward. The double hand-steering wheels are placed at the fore end of the poop. A fore-and-aft gangway connects the poop and forecastle decks, and upon skid beams at the same level are placed two steam launches, jolly boat, cutters and gig with special facilities for quickly lowering. On the forecastle deck is placed a nickel-steel chart and wheel house for steam-steering gear, forward of which is a 4-inch gun with a range of 120 degrees from forward aft. A steam capstan for working the anchors, with a neat collapsible anchor crane, is also provided.

Under the poop, saloons and staterooms are arranged for the President when upon diplomatic service, also for the commander, second commander, executive officer, doctor and paymaster, together with dining saloon, pantry, office and toilet and bath rooms. Between the poop and forecastle, mounted upon sponsons, are two 6-pounder rapid-fire guns aft and two 4-inch rapid-fire guns amidships, with ammunition trunks from the magazines in close proximity. Within the boiler casings are installed three steam galleys for ship's officers, crew and troops, also the firemen's washplace. In the forward deckhouse is located a well-equipped sick bay, having the necessary bath, swinging cots and every surgical appliance.

Under the forecastle, in separate rooms, nine warrant officers are installed, the remainder of the crew, numbering sixty, being berthed in hammocks. Portable mess tables and seats are provided for their use. A powerful steam windlass for working the cables is placed in the forward part of the forecastle. Ample facilities for quick coaling are given through numerous scuttles

in the upper deck. A steam winch is provided aft on the upper deck for hoisting gear on board. The hammock berthing at the sides of the vessel on the upper deck gives storage accommodation for hammocks. On the berth deck fourteen staterooms, four toilet and bath rooms, three mess rooms and attendant pantries, aft of the engines, give accommodation for the ship's officers, six engineers, ten cadets and one chief and sixteen troop officers. Forward of these the ice machine, refrigerating room, two powerful fans for ventilating the various spaces, and pipe berths for 160 troops are provided, whilst at the bow of the vessel is located the torpedo room and discharging tube with air compressor and other appliances.

In the forward hold space is allotted for ninety troops in standee berths, forward of which are arranged the gunner's, carpenter's, boatswain's and electrical stores and cable lockers. In the after hold magazines are provided for nearly 4,000 rounds of 4 and 6-pounder gun ammunition, together with bread rooms, paymaster's stores, sail room, etc.

The machinery is well protected above water by the arrangement of side coal bunkers, and the vessel is lighted throughout by electricity. There are two inverted, three-cylinder, triple-expansion engines fitted with Stevenson steam-reversing gear. The diameter of the high-pressure cylinder is 14 inches, the intermediate-pressure cylinder, 22 inches; the low-pressure cylinder, 36 inches, and the stroke, 24 inches. The exhaust from each engine passes to an independent condenser, which is placed outboard of the engine. In the engine room is placed an auxiliary feed pump, a fire and bilge pump, a sanitary pump, two air pumps, an evaporating and distilling plant and an electric-light plant. The evaporator has a capacity of 2,500 gallons every twenty-four hours. This output can be directed to main boilers for feed water, or to the fresh-water storage tanks as may be desired. The electric-light plant consists of two $7\frac{1}{2}$ direct-connected generators of the direct-current type. One is used for lighting the ship, while the other supplies the current for the searchlights.

The boiler room is of the closed-stokehold type with two 48-

inch blowers to supply the air pressure for the forced draft. Two Mosher water-tube boilers supply steam at a pressure of 250 pounds and have a total grate area of 81 square feet. The total coal-bunker capacity is 170 tons under ordinary cruising speed. This would allow a radius of 2,000 knots, while under forced draft it would admit of a radius of 1,500 knots. In the boiler room there is located the main feed pump, a feed-water heater, and above, on the main-deck level, a donkey boiler of sufficient capacity to operate the auxiliary machinery when the main boilers are not in operation. Under the engine and boiler spaces in the inner-bottom compartments is stored the reserve feed water for the boilers.—"Marine Review."

RUSSIA.

Bayan.—This armored cruiser has already, on her preliminary trials, exceeded the designed speed of 21 knots. Her engines are designed to develop 17,000 I.H.P., steam being supplied by twenty-six Belleville boilers, fitted with economizers.

Buistri and Stremitelni.—The "Kronstadtski Viestnik" states that the new Russian deep-sea torpedo boats *Buistri*, built by the Nevski Shipbuilding Works, and *Stremitelni*, built by Kreiton and Company, of St. Petersburg, have recently undergone their trials, the former boat making a maximum speed of 27.96 knots, and an average of 27.1 knots, and the latter a maximum of 26.57, and an average of 26.19 knots.

Orel and Orleg.—The "Kronstadtski Viestnik" states that the ceremony of the *zakladka* of the new Russian cruiser *Orleg* took place on July 19, at the New Admiralty Yards, St. Petersburg. The Czar first put a silver tablet in position, and afterwards hammered in the first rivet of the steel plate which covered it. The *Orleg* was begun on November 21, last year, and up to the present time about 1,100 tons of steel has been used in her construction. Her length will be 433 feet 10 inches; beam, 54 feet 5½ inches; draught, 20 feet 7¼ inches; displacement, 6,675½ tons. Later the Czar was present at the launch of the new Russian battleship *Orel*, at Galerny Island. She was begun on June 2, 1900, and up to the present time 56.3 per cent. of the work on her has

been completed. Her length will be 398 feet 1 inch; beam, 76 feet; draught, 26 feet; displacement when fully equipped, 13,516 tons; engines, 15,800 horsepower, supplied by twenty Belleville boilers; speed, 18 knots. She will carry sixty-two guns, consisting of 12-inch, 6-inch, 2.95-inch, 1.85-inch, 1.45-inch, and 2½-inch (landing) guns, and also four torpedo tubes, two above water and two submerged. The steel used in her construction was made at the Putilovski Steel Works, and the armor of Krupp steel, at the Admiralty, Izhorski, and other works.

Russian Cruisers.—The "Kronstadtski Viestnik" states that the Nevski Engineering Works, St. Petersburg, have received an order for two new Russian cruisers of 6,000 tons. At the same works an order is expected for 30 torpedo boats of 420 tons. The three torpedo boats recently completed at the works are of 350 tons only, this being up to the present the usual tonnage of Russian deep-sea torpedo boats. The third of these boats, the *Bravi*, underwent her trials on August 11th, when her speed averaged a trifle more than 26 knots, not quite equaling the speed of her sister boats, the *Boiki* and *Buinl.* At the trials of the *Bogatyr*, a new Russian cruiser of 6,750 tons and engines of 20,000 H.P., the average speed attained was 23.45 knots, though at her builders' trials as much as 24.21 knots was made. The following are the results of the trials of the new Russian cruiser *Askold* with her engines revolving at different rates: With 55 revolutions, 10.87 knots; 70 revolutions, 13.70 knots; 85 revolutions, 16.35 knots; 100 revolutions, 18.85 knots; 107 revolutions, 19.5 knots; and 115 revolutions, 20.11 knots.

SWEDEN.

Mode.—The contract for this boat was let in October last to Messrs. Yarrow & Co., and on August 28 the official trial was made, so that only ten months were needed for the construction of the craft. The builders had a fairly free hand as to the details of the design; but were required to provide a boat capable of making 31 knots when carrying a load of 35 tons on board. This guarantee was very easily realized, as during a three-hour run a speed of no less than 32.4 knots was maintained, although

the engines with which the boat is fitted are only designed to furnish 6,500 horsepower.

In fact, the speed reached is greater than that of any boat now belonging to the British Navy, although some of the destroyers built for the latter are fitted with very much more powerful engines; in one case, indeed, engines of 10,000 indicated horsepower have been fitted; but the speed at which the boat has been taken over is only about 31 knots. That the excellent results obtained in the *Mode* have not been reached by an undue lightening of scantlings is clearly proved by the fact that ten very similar boats built by Messrs. Yarrow for the Japanese Navy have been navigated without accident out from this country to Japan. It is, of course, possible that some of these boats had fair-weather trips, but it is inconceivable that the whole ten could each have steamed over the 11,000 miles between London and Yokohama without very heavy weather being met with by one or other of the flotilla. In short, it cannot be doubted that the low ratio of power to speed is due mainly to the excellent lines of the hull.

Though we have not had an opportunity of seeing the *Mode* at a full-speed trial, yet at 25 knots or so we noticed that the craft slipped through the water with astonishingly little wave-making action, and, the engines being balanced on the Yarrow-Schlick-Tweedy system, there was practically no vibration. The hull measures 220 feet 3 inches over all, and is 20 feet 6 inches wide, whilst the displacement is 400 tons. The bunkers will hold enough coal to take the boat right across the Atlantic at a speed of 13 knots. There are four Yarrow water-tube boilers, each of which has 3,000 square feet of heating surface, and is designed for a working pressure of 240 pounds per square inch. There are two large stokeholds. The fan for the forced draft runs on a vertical spindle, and can thus be fixed well out of the way over the center of the stokehold, occupying what would otherwise be useless space. The engines in the three-hours' trial indicated a mean of 6,800 horsepower.

There are two sets of these engines, which are of the four-cylinder triple-expansion type, there being one high-pressure cylinder, 20½ inches in diameter, one intermediate, 31½ inches in

diameter, and two low-pressure cylinders, 34 inches in diameter, the stroke in all cases being 18 inches. The reversing gear is very light and neat. This lever controls the distributing valve of a steam-reversing gear, fixed between the columns near the center of the engine. This distributing valve is balanced, so that it is very easily moved, and there is, of course, an "overtaking motion" provided which shuts off steam from the reversing cylinder as soon as the links are over to the desired amount. Any further motion of the reversing piston will cause steam to be admitted to the other side of it; and in actual running this piston is kept floating slightly about its mean position. All the hand wheels for steam valves have their rims formed out of a spiral coil of wire. This spiral, having a small area through which heat can be conducted and a very large radiating surface, always remains cool, and it affords, moreover, a capital grip for the hands.—London "Engineering."

The following is a record of the official trial of the torpedo-boat destroyer *Mode*. Load carried, 35 tons; runs on the Maplin mile; weather fine; light breeze; sea calm; left yard at Poplar 10·45 A. M.; returned to Poplar 7·35 P. M.

THREE-HOURS' OFFICIAL TRIAL, AUGUST 28, 1902.

Run.	Hour.	Air pressure in stokehold.	Revolutions per minute.	Time.	Speed.	First mean.	Second mean.	Admiralty mean.
	P. m.	*inches.*		*m. s.*	*knots.*			
1	1·6	1.1	418.5	1 53.1	31.840			
						32.136		
2	1·16	1	419.1	1 51	32.432		32.155	
						32.173		
3	1·26	1	417	1 52.8	31.914		32.217	32.130 on measured mile.
						32.261		
4	1·37	.9	422	1 50.4	32.608		32.170	
						32.079		
5	1·47	1.2	414.1	1 54.1	31.551		31.977	
						31.876		
6	1·58	1	414.8	1 51.8	32.2			

Mean for the three-hours' trial, 240 pounds steam, 72 pounds in first-intermediate receiver, 15 pounds in second-intermediate receiver; vacuum, 21 inches; air pressure in stokeholds, 1.5 inches; mean revolutions per minute, 421.4; mean speed during three hours, 32.428 knots.

Aran.—The official trial has been completed of the coast-defense vessel *Aran*, built for the Swedish Navy. She is 3,700 tons, 6,500 horsepower, and furnished with eight Yarrow water-tube boilers. The mean speed exceeded the contract speed by six-tenths of a knot, amounting to 17¼ knots, and the horsepower exceeded the contract power by 1,000. The coal consumption, including the steam for the auxiliary engines, amounted to 1.78 pounds per horsepower per hour.

The armament of the craft consists of two 18-inch revolving torpedo tubes placed aft of the engine-room, which can be fired over either side at an angle, and of six 57-millimeter quick-firers. An electric searchlight is mounted over the chart house.

The contractors' report of the official trial is given below. It should be stated that this trial was run immediately after a single preliminary trial, it having been found quite unnecessary to nurse the boat through a series of preliminary runs before entering on the official one.

MERCHANT STEAMERS.

The New German High-Speed Liner Kaiser Wilhelm II.—The launch of the new North German Lloyd high-speed Atlantic liner *Kaiser Wilhelm II* is an event of the first importance, as the vessel is not only the largest ship yet built, but is to be the fastest, her propelling machinery representing an aggregate of 40,000 indicated horsepower, which is greater than has ever before been placed in one vessel. Nor is there any speculative element associated either with the inception or design of this latest of leviathans, for the company which owns her have already in service two ships only second in size and speed to this vessel, while the constructors, the Vulcan Company, of Stettin, have completed three vessels which occupy the top place amongst the world's steamships. The North German Lloyd, in ordering this ship, thus clearly indicates that the belief entertained in this country against the financial success of these huge liners has not been borne out by experience; firstly, with the *Kaiser Wilhelm der Grosse*, which has now been running for three or four years; and, secondly, with the *Kronprinz Wilhelm*, completed a year ago. In point of fact, the company finds that, during the busy season, extending from July to October, every berth in the ship is in demand, and the number of disappointed applicants for accommodation equals, as a rule, quite 33 per cent. of the total capacity of the ship. In the off season no difficulty is found in insuring that 75 per cent. of the accommodation available is utilized even at the high rates charged, a result due to the seaworthiness, speed and comfort provided. Indeed, we have been informed that the high-speed liners named have, on every trip, more than paid their way, and that, too, without any Government subvention beyond the ordinary mail allowances fixed on a basis common to all nations.

The choice of builders is also a pronounced demonstration of the mechanical and economical efficiency of the preceding ships.

Indeed, the Vulcan Company, alike in their German war vessels and merchant ships, have had an uninterrupted success, and the admirable equipment of their establishments, combined with the great experience of the directors—Messrs. Stahl, Zimmermann and Flohr—gives confidence that this new vessel will repeat the splendid performances of her predecessors. As with the preceding ship, many experiments have been made with models to determine the lines offering the least resistance to propulsion.

The vessel is built on the double-bottom principle, with twenty-six watertight divisions between the bottoms, and the work was done almost entirely by hydraulic riveting, the riveter being supported on a temporary gantry built over the framing. In the molded depth of the ship there are four decks, and sixteen transverse bulkheads extending to the upper deck, with a longitudinal bulkhead through the engine rooms, which are thus divided, as will presently be explained, into four separate compartments, making the number of watertight compartments nineteen in all. The bulkheads are so arranged that in case of the flooding of any two adjoining spaces, the ship would still float; and the scantlings have been arranged according to the most recent specifications of the German Lloyd, and so proportioned that the bulkheads can resist the full head of water pressure on one side only. The structure at the stern of the ship, is exceptionally strong. The framing is bossed out, so that the greater part of the propeller shaft is within the structure itself, and can thus be examined at any time, while at the extreme after end strong spectacle framing is provided for the plating. Another interesting feature is the bossing out of the framing for the better accommodation of the steering machinery, which is placed at the tiller head. Although the stern frame shows an aperture, the propellers do not overlap.

Above the molded dimensions there are four decks—one more than in previous Atlantic liners. Over the upper deck, which is the top level of the molded part of the structure, there is a spar deck right fore-and-aft, the middle part serving for a promenade. There is a forecastle, amidship deck house 135 meters long (442 feet 11 inches) and 15 meters (49 feet) broad,

and a poop house 24 meters (78 feet 9 inches) long. The roof of the midship deck house extends for the full width of the ship and over the poop, forming an upper promenade deck 164 meters (538 feet) long. There is a deck house 133.5 meters (438 feet) long, on this upper promenade deck, over which again the boat deck lies. In this way there are provided for the convenience of passengers wishing for the open air, several broad and shaded promenades at the side of the deck houses. In existing passenger steamers only one such promenade deck is provided. A large area of the boat deck is also available for the same purpose.

The principal rooms are on the decks above the molded structure. The ship carries a great population—something like 2,500—but she is of immense size. Her chief dimensions are:

Length over deck	215.34 meters (706 feet 6 inches).
Breadth	21.94 meters (72 feet 0 inches).
Depth to side of upper deck	13.46 meters (44 feet 2 inches).
Depth to side of lower promenade decks	16.00 meters (52 feet 6 inches).

TABLE SHOWING DIMENSIONS OF THE

Name of ship	*Kaiser Wilhelm II.*	*Kronprinz Wilhelm.*	*Deutschland.*
builders	Vulcan Company, of Stettin.	Vulcan Company, of Stettin.	Vulcan Company, of Stettin.
owning company	North German Lloyd.	North German Lloyd.	Hamburg-American.
Year when built	1902	1901.	1900
Length over all	706 feet 6 inches.	663 feet.	684 feet.
between perpendiculars	...	...	662 feet 9 inches.
Breadth	72 feet.	66 feet.	67 feet.
Depth, molded	52 feet 6 inches.	43 feet.	44 feet.
Gross tonnage, tons	20,000	15,000	16,502
Draught	29 feet.	29 feet.	29 feet.
Displacement, tons	26,000	21,300	23,620
Number of passengers (first)	775	650	693
(second)	343	350	302
(third)	770	600	288
Type of engine	Four sets, four-cylinder quadruple-expansion.	Two sets, six-cylinder quadruple-expansion.	Six-cylinder quadruple-expansion.
Number of cranks	6	4	4
Diameter of cylinders	Four of 37.4 in.; four of 49.2 in.; four of 74.8 in.; four of 112.2 in.	Two of 34.2 in.; one of 68.8 in.; one of 98.4 in.; two of 102.3 in.	Two of 36.61 in., 73.6 in., 103.9 in.; two of 106.3 in.
Stroke of piston, inches	70.86	70.8	72.8
Number and type of boiler	Twelve double-ended; seven single-ended.	Twelve double-ended; four single-ended.	Twelve double-ended; four single-ended.
Number of furnaces	124	128	112
Steam pressure, pounds	225	213	220
Total heating surface, square feet	107,643	93,865	85,468
grate area, square feet	3,121	2,702	2,188
Draft	Open stokehold.	Open stokehold.	Howden's.
Total indicated horsepower	38,000 to 40,000	36,000	36,000
Highest mean speed on Atlantic passage, knots	23½ to 24 (Estimated).	23.25 to 23.5	23.25 to 23.5

*Speed on trial trip.

The displacement of the loaded vessel is 26,000 tons. The measurement capacity is, in round figures, 20,000 tons gross register, whereas the *Deutschland*, the largest of existing German steamers, has a displacement of 23,200 tons and a measurement capacity of 16,500 gross register tons. In the Table we give the principal particulars of the leading Atlantic liners, and it will be seen that the four best ships are now German-owned. The *Kaiser Wilhelm II* is 2 feet 6 inches longer than the *Oceanic*, and 6 feet 6 inches longer than the *Celtic;* she carries a greater number of passengers of all classes, while her number of first-class passengers is almost double that of the two ships named.

Electricity is largely employed on the ship, partly for the convenience of the passengers and partly for the security of the vessel. Electric-bell communication is provided, leading from all the saloons, first and second-class cabins, and the cabins of the principal officers, to the pantries. In the smoking saloons of the first and second class, and in the Vienna café, there are

KAISER WILHELM II AND HER COMPETITORS.

Kaiser Wilhelm der Grosse.	*Campania* and *Lucania.*	*Oceanic.*	*St. Paul* and *St. Louis.*	*La Lorraine* and *La Savoie.*
Vulcan Company, of Stettin.	Fairfield Company, of Glasgow.	Harland and Wolff, of Belfast.	Cramp, of Philadelphia.	French Trans-Atlantic.
North German Lloyd.	Cunard.	White Star.	American.	Ditto.
1898	1893	1899	1895	1900
648 feet 7½ inches.	622 feet.	704 feet.	554.2 feet.	582 feet 4 inches.
625 feet.	600 feet.	685 feet.	535.8 feet.	557 feet 8 inches.
66 feet.	65 feet 2 inches.	68.4 feet.	63 feet.	60 feet 6 inches.
43 feet.	41 feet 6 inches.	49 feet.	42 feet.	39 feet 4½ inches.
14,349	12,500	17,274	11,629	11,869
28 feet.	25 feet.	32 feet 6 inches.	26 feet.	25 feet 6 inches.
20,880	18,000	28,500	16,000	15,400
590	600	410	320	440
354	400	300	200	120
640	700	1,000	800	400
Four-cylinder triple-expansion.	Five-cylinder triple-expansion.	Four-cylinder triple-expansion.	Six-cylinder quadruple-expansion.	Four-cylinder triple-expansion.
4	3	4	4	4
One of 52 in., 89.7 in.; two of 96.4 inch.	Two of 37 in.; one of 79 in.; two of 98 in.	One of 47.5 in., 79 in.; two of 93 in.	Two of 28 in.; one of 55 in.; one of 77 in.; two of 77 in.	One of 43.2 in.; one of 68.4 in.; two of 80.3 in.
68.8	69	72	60	66.9
Twelve double-ended; two single-ended.	Twelve double-ended; one single-ended.	Fifteen double-ended.	Six double-ended; four single-ended.	Sixteen single-ended.
104	102	96	64	64
178	165	192	200	175
84,285	82,000	74,686	40,320	45,571
2,618	2,630	1,962	1,144	1,225
Open stokehold.	Open stokehold.	Assisted draft.	Howden's	Howden's
30,000	30,000	27,000	18,000	22,000
22.5 to 23	22.01	20.72	21.08	21.90*

These vessels have not yet attained their maximum on the Atlantic.

electric cigar lighters, and in the passenger cabins of the first and second class, provision is made for electric heaters. A complete telephone installation of loud-speaking telephones is provided from the bridge to the two engine rooms and to the telephone house on the aft deck. There is also a telephone installation from the captain's cabin to the rooms of the chief engineers, first officers, paymaster's and doctor's rooms, as well as the steward's office; and from the steward's office to the first-class passengers' pantry, and to the paymaster. A complete system of alarm bells is provided for the security of the ship—thirty-three bells for the ship and fourteen for the engines. There is a complete fire-extinguishing installation, with twenty-one bells communicating with the various quarters of the crew; also a complete fire-alarm installation, with seventeen fire-alarms distributed over the whole of the decks. There is an electric signaling arrangement communicating with a bulkhead indicator on the bridge.

All the spaces below the upper deck, lying between the watertight bulkheads, are provided with central gangways, whereby it is possible, without disturbing the movements of the passengers, to attend to such duties as keeping closed the watertight bulkhead doors below the upper deck. Of the fifty-two watertight doors, twenty-four bulkhead doors are provided with the Dörr closing device, enabling them to be shut from the navigating bridge. By means of a bulkhead indicator in the chart house, the captain can at once see whether all, or which of the watertight doors are closed.

Any water entering the ship can be pumped out by means of the steam pumps installed, consisting of four centrifugal bilge pumps, four engine-room bilge pumps, four steam boiler-room bilge pumps and five duplex pumps, which can together deal with 9,360 tons of water per hour. There are twenty lifeboats and six semi-collapsible boats. Some of the lifeboats are of wood; the others, as well as the semi-folding boats, are of galvanized steel plates. To quicken the process of lowering the boats to the water, four of the davits are arranged with steam gear.

To fulfil the conditions of the Imperial German Navy, the vessel has been adapted for mounting a large number of guns, in order to serve as an auxiliary cruiser in case of war. To this end also the rudder and steering gear are arranged to lie under water, which accounts for the bossing out to which we have referred.

The vessel is fitted with every convenience for navigation. Special care has been taken in the design and construction of the anchor gear. The windlasses and warping capstans are supplied by Messrs. Napier Brothers, Limited, the famous windlass, capstan and steering-engine makers. The cables are 3¼ inches in diameter, iron, and the cable wheels for working them are placed on the lower promenade deck, fitted on vertical spindles, and fitted with Napier patent self-holding differential brakes of massive proportions, disconnecting driving discs, and scroll hand wheels, baseplates and chain pipes. These parts are all made of cast or forged steel and gun metal, no cast iron being used in these parts of the gears. Three warping capstans are placed on the forecastle deck, two being abreast and the third somewhat forward of them at the middle line.

The capstans, pawl plates and deck bosses are made of cast steel, bushed with gun metal, and with polished gun-metal top plates. The vertical spindles of the windlasses and capstans are carried to the upper deck and fitted with worm wheels worked through worms and wheel gearing from two pairs of engines, having cylinders 18 inches in diameter by 14 inches stroke, and 15 inches in diameter by 12 inches stroke. The gearing and shafting with disconnecting clutches, is so arranged that any of the capstans or windlasses can be worked from either engine independently.

The engines for working the middle-line capstan are placed on the lower promenade deck. All the gearing is made of cast steel and gun metal, all wheels having machine-cut teeth. The worms are of forged steel, accurately turned. The lubricating arrangements have been carefully considered, and separate oil boxes are fitted for all the moving parts, and arranged for syphons and ordinary worsteds. Gun-metal hand wheels and pedestals

for controlling the engines and gearing are placed at the several stations for convenience in working.

The cable and warping arrangements at the after part of the vessel have a cable holder for working a 2-inch cable, and fitted with Napier's patent self-holding brake, base plate and chain pipe, placed on the lower promenade deck at the middle line, and the vertical spindle is carried to the upper deck and worked by worm gearing from engines with cylinders 15 inches in diameter by 12 inches stroke. The upper end of the vertical spindle carries a large capstan or drum for warping purposes, so arranged that the cable holder may be coupled or uncoupled as required, and the cable worked independently of the capstan or drum. Two smaller capstans, for warping purposes only, are fitted on the lower promenade deck, one on each side of the deck house, each worked by an independent engine with cylinders 11 inches in diameter by 10 inches stroke. This company has every appliance and facility for turning out these heavy gears in the shortest possible time, and although the parts were exceptionally large in this case, they were made as light as possible, consistent with strength and efficiency.

The engine and boiler installations, also built by the Vulcan Company, consist of four four-cylinder, three-crank, quadruple-expansion engines, and balanced on the Schlick system; they will indicate altogether from 38,000 to 40,000 horsepower. These powerful engines drive two four-bladed bronze screw propellers of 6.95 meters (22 feet 9.6 inches) diameter. Great importance is naturally attached to the excellence of the material of the shafting; and the crank shafts and the thrust shaft, 635 millimeters (25 inches) in diameter, are made of the best nickel-steel; the screw shaft, 645 millimeters (25.4 inches) thick, is of crucible steel, and the whole connecting shafting is of Siemens-Martin steel.

In order to keep the watertight compartments utilized for accommodating the machinery as short as possible, for the greater safety of the vessel in case of collision and fracture of the skin plating of the ship in their neighborhood, it was decided to divide the machinery into four sets, and to place each in separate rooms formed by transverse and longitudinal bulkheads. This necessitated a particular construction of the engines, and the

arrangement is such that in each room there is fitted a self-contained four-cylinder quadruple engine working on three cranks. Each double set is balanced on the Schlick system. The high-pressure cylinder is placed above the first intermediate, the arrangement resembling the Wolff system. Next to the first intermediate comes the second intermediate, and next the low-pressure cylinder. But for balancing purposes the double set is arranged so that the two tandem cylinders adjoin each other, although with the bulkhead between. Each high-pressure cylinder is provided with a second stop valve, in addition to the main stop valve. The levers for working the auxiliary valves and the reversing engines are so arranged that the two engines on each shaft can be worked from either of the two engine rooms; but when the engines are working under normal conditions, the engineer's platform will be in the forward engine room. Should the forward engine room be filled with water through misadventure, it is possible to drive the after engine separately, and the same can be done with the forward engine in case of the after engine being out of order.

The auxiliary engines are arranged in accordance with the principle of any of the four sets of main propelling machinery working independently, and thus each engine room is self-contained, having one condenser, one centrifugal pump, one Weir air-pump engine, one single Weir heater and feed pump, and one double Weir boiler-feed pump, while one heater and one feed-water filter is fixed up for each two of the two feed pumps. For other pumping duties there are arranged in each engine room two independent duplex pumps, so that the complete safety of each room is secured.

The principal dimensions of the main engines are:

Diameter of high-pressure cylinder	950 mm.	(37.4 in.)
first intermediate cylinder	1,250 mm.	(49.2 in.)
second intermediate cylinder	1,900 mm.	(74.8 in.)
low-pressure cylinder	2,850 mm.	(112-2 in.)
Stroke of each cylinder	1,800 mm.	(70.8 in.)
Diameter of crank shaft of forward engine	530 mm.	(20.87 in.)
after engine	635 mm.	(25 in.)
Cooling surface of each condenser	1,090 sq. m.	(11,732 sq. ft.)
Estimated revolutions per minute	80	

The boiler installation consists of twelve double-ended and seven single-ended boilers. The arrangement of these boilers is as follows: Starting aft, in the first boiler room there are three double-ended boilers; in the second boiler room, three double-ended and three single-ended boilers; in the third boiler room, three double-ended and three single-ended boilers; while in the forward boiler room there are three double-ended and one single-ended boilers. This distribution is adopted in order to facilitate as much as possible the transport of coal to the boilers—a matter which has had very special attention on this steamer.

The auxiliary engines in the boiler room are: In each boiler room, one large feed pump and two ash ejectors, a steam ash winch for use when in harbor, with other necessary apparatus. There is, further, in the third boiler room a ballast pump. On deck, above all the boiler rooms, there are eight fans, which supply the boiler rooms with air when there is not sufficient wind.

The arrangement of shafting and stern-tube propeller, etc., is exactly the same as in the *Kaiser Wilhelm der Grosse*, *Kronprinz Wilhelm* and *Deutschland*. The total heating surface of the nineteen boilers is 10,000 square meters (107,643 square feet), and the grate area 290 square meters (3,121 square feet), with a boiler pressure of 15 atmospheres (225 pounds). The boilers work with natural draft, as in the case of the *Kaiser Wilhelm der Grosse* and the *Kronprinz Wilhelm*.

The number of engines on board, including the main engines, is 79, and there are 124 steam cylinders.

The launching weight of this powerful vessel amounted to 11,200 tons, while that of the *Deutschland* was 9,300 tons, and of the *Kronprinz Wilhelm*, 8,950 tons.—London "Engineering."

New White Star Liner Cedric.—Following are particulars of the new White Star liner *Cedric*, perhaps the largest vessel in the world, launched recently from Harland & Wolff's yard in Belfast: The length of the *Cedric* is 700 feet, her beam is 75 feet (7 feet wider than the *Oceanic*), and her depth 49⅓ feet. She is about 21,000 tons gross. The displacement at her load draught will be 37,870 tons. The *Cedric* has no fewer than nine decks, and is built on the cellular double-bottom principle, being divided

into numerous watertight compartments. The engines are of the Harland & Wolff quadruple-expansion balance type. The *Cedric* has accommodation for about 3,000 passengers, besides quarters for a crew of about 350. In addition to the ordinary state rooms there are suites consisting of bed, sitting and bath rooms for families. There are also single-berth state rooms, practically a new feature in ocean liners. The first-class accommodation is all arranged amidships on the upper decks, and the number of such passengers provided for is 365. The grand dining saloon is on the upper deck, and extends the full width of the ship—75 feet. It contains seating accommodation for over 300 persons. Aft, on the upper and bridge decks, there is accommodation for 160 second-class passengers, excellent not only in regard to bedrooms, baths and lavatories, but in saloon, smoking room and library. An unusually large number of third-class passengers are provided for on the upper-middle and lower decks, some in separate cabins and others in open berths forward. There are separate galleys or kitchens for all three classes of passengers; also separate pantries equipped in the most approved and modern style.—Engineers' "Gazette."

YACHTS.

The Steam Yacht Arrow.—Over a measured course, the steam yacht *Arrow* recently covered a nautical mile in exactly one minute and 32 seconds, or at the rate of 39.13 knots an hour. This is equivalent to 45 statute miles an hour, and constitutes a new record for vessels of any kind whatsoever. The *Arrow* was designed by Charles D. Mosher, of New York City, whose name is identified with the production of some of the fastest steam craft of the world, his *Ellide*, a smaller vessel than the *Arrow*, having steamed over the same measured mile at a rate of 34.73 knots an hour. Although the speed aimed at by the *Arrow* was extraordinarily high, namely, 40 knots an hour, the uniform success which has attended the high-speed trials of the Mosher boats led those who have followed the performance of this craft to expect that the designed speed would be reached.

The *Arrow* is a twin-screw yacht 130 feet 4 inches total length, 12 feet 6 inches beam, 3 feet 6 inches normal draught, with a displacement on that draught of 66 tons. In designing the vessel particular attention was paid to the question of securing the greatest possible strength for the least weight of material; and the hull is unusually light considering the great power, 4,000 horsepower, which is developed when the vessel is at full speed. The lines are similar to those with which we are familiar in the torpedo-boat destroyer, but they are greatly refined; and, owing to the fact that the greatest beam lies well aft, and that this beam is continued out in the flat stern, the lines of the yacht are remarkably easy and well adapted to securing high speed results. The great sweetness of her model was shown in the fact that when the *Arrow* was steaming, in the earlier part of the mile trial, at a speed of over 40 knots an hour, she made remarkably little fuss, there being no lofty and crested bow wave, such as is seen at the high-speed trials of torpedo boats.

The construction of the boat is composite in character, steel frames below the water line and aluminum above, except in the boiler and engine-room spaces, where they are of steel throughout. Keelson, lower plates, reverse frames, bunkers, bulkheads, boiler saddles, engine foundations and other details are also of steel. The sides are double planked with mahogany, which is brought to a smooth, fair surface and highly finished. Deck beams are aluminum bulb angles, while aluminum is used also for many other details. The vessel is strengthened longitudinally by diagonal strappings of steel plates.

The motive power consists of two Mosher water-tube boilers, containing a grate surface of 120 square feet and a heating surface of 5,540 square feet, the weight, empty, of each boiler being 6.43 tons. The boilers were designed to supply steam at 440 pounds to the square inch, although on the trial the pressure never exceeded 400 pounds to the square inch, that being the limit allowed by the inspectors. The twin engines are of a type which has been specially designed for these high-speed craft. They are quadruple-expansion, with cylinders of 11, 17, 24 and 32 inches diameter by 15 inches stroke. The working pressure varies from 350 to 400 pounds per square inch and the revolutions from 540 to 600. The calculated power developed under 540 revolutions and 350 pounds pressure at the engine is 4,000 horsepower. Both engines exhaust into one condenser with a cooling surface of 2,760 square feet. Between the steam cylinders there is installed a series of re-heaters, each one of which is capable of supplying the entire thermal equivalent of the work expended during the expansion, thus keeping the steam in a superheated condition throughout its working cycle. These re-heaters dry the steam and prevent cylinder condensation.

The feed water, before returning to the boilers, is heated in four-stage feed-water heaters, being finally delivered to the boiler at a temperature of about 350 degrees. From what we have said it will be seen that the development of power is very high for the weights involved. Thus the weight of the boilers per square foot of heating surface, when they are full of water, is 6.3 pounds. The indicated horsepower per square foot of grate surface is 33,

while the weight in pounds per horsepower of engines, boilers, including water, and all auxiliaries, is only 17.78 pounds.

Points which make for high economy, and hence for a large return of power per pound of boiler and pound of coal may be summarized as follows: Great initial pressure (from 100 to 150 pounds greater than the common practice in high speed boats); the considerable wire-drawing from the boiler to the engine, tending to dry and superheat the steam and reduce the condensation, results which are also enhanced by the action of the reheaters on the cylinders; and the reduction of the cylinder clearances in the engine to a very low value.

With regard to the results actually obtained, if we would estimate them in their full value, we must bear in mind that the designer, who has always superintended the speed trials of the earlier vessels, was absent on this occasion. There were, moreover, certain untoward circumstances connected with the trial which undoubtedly prevented the attainment of the fullest speed of the vessel. Judging from the fact that provision had been made by those in charge of the trial, for instantly opening the four safety valves on the two boilers, it would seem that there was a certain measure of nervousness in the engine-room force which, in itself, would not conduce to securing the highest results. Cords had been tied to the safety valves and an engineer placed so that he could instantly open all four valves.

The craft came down to the line at a speed which must have been something over 40 knots an hour, and had proceeded, under a boiler pressure of 400 pounds per square inch, over about one-quarter of the mile course, when one of the safety valves lifted. At this instant the engineer told off to watch the valves, pulled the rope and released the other three, so that the *Arrow* completed the remaining three-fourths of the course with an enormous volume of steam blowing from her boilers. As a consequence the pressure ran down to 250 pounds, at which pressure it stood when the mile was completed. There was, in consequence, a visible falling off of the speed; but in spite of this the estimated speed of 40 knots an hour was closely approximated, the actual speed being 39.13 knots an hour. The sighting of the marks

was done by one observer and the stop watch was held by another, the result being carefully checked by several watches on board, all of which agreed with the result given out by the timekeeper.

In discussing the results, the designer, Mr. Mosher, points out that the *Arrow* was drawing about five inches more than her designed normal draught of three feet six inches; that the boiler pressure, even at the starting point, was forty pounds below the designed pressure; and that the vessel had not been out of the water for several months and, therefore, her bottom was not as clean as could be desired for a speed trial. These considerations would seem to justify the belief that when steaming on her designed lines and with a perfectly clean bottom, the *Arrow* would make, and probably somewhat exceed, a speed of 40 knots an hour.—"Scientific American."

BOOKS AND CATALOGUES.

INGENIEURS TASCHENBUCH.—This is the eighteenth edition of the engineers pocket-book edited by the Academical Society "Hütte" and published by Wilhelm Ernst & Sohn, Berlin. It is in two volumes, containing 2,066 pages of closely printed matter and covering the entire field of engineering.

The matter is divided into twenty-one chapters including an appendix. In the preface are mentioned thirty-four authorities of Germany and Austria, all eminent men in their respective professions, who have supervised the revision and enlargement of the different chapters.

As in former editions, the guide in the enlargement and revision of this timely work was from the view point of science. Due to the expansion of science in all branches of engineering the various chapters have been extended.

The chapter on *heat*, including the *mechanics of gases* and *vapors*, has been entirely rewritten; also the chapters on *turbines*, *lifting apparatus*, *geodesy* and *naval architecture*. A new chapter on *combustion motors* has been substituted in place of the former one on gas engines; this is the first attempt to present this difficult branch theoretically. Other chapters that have received due attention are city water supply, sewerage, highway construction and bridge building. The chapter on technology, with the exception of the manufacture of gas, has been omitted.

The first volume embraces the following chapters: Mathematics, applied mechanics including the mechanics of gases and vapors, strength of materials, materials, machine elements, motors and work-performing machines. The second volume contains building construction, city water supply, sewerage, heating and ventilation, highway construction, statics of building construction, bridge building, naval architecture and marine engineering, railway construction, manufacture of steel and iron, electricity,

manufacture of gas, and an appendix containing tables of coins, comparisons of weights and measures of various countries, etc.

The entire work is systematically arranged and brought up to date. The printing is clear and the cuts are excellent. Of course, the work is adapted to the practice of continental Europe, though much of it can be applied anywhere.

The work is a typical product of German diligence and conscientiousness, and a credit to the publishers.

A similar work to this adapted for American practice would no doubt be welcomed by the engineering profession. The price for the two volumes, bound in pliable leather, is 16 marks.

VULCABESTON.—The JOURNAL has lately received a neat little catalogue from the H. W. Johns-Manville Co., giving a list of packings made from this well-known material, and strong testimonials as to its efficiency.

The specialties covered are sheet packings for steam, gas and hot air, ammonia, alkalis, etc., piston-rod packing, gaskets, molded gaskets, washers and concave and convex packing rings.

The catalogue is very complete, and any one interested in the subject can obtain a copy of it upon request.

ASSOCIATION NOTES.

At a meeting of the Society held on October 8, 1902, in the office of the Engineer-in-Chief, Navy Department, the following candidates for President, Secretary-Treasurer and Council of the Society were nominated:

For President: Rear Admiral John D. Ford, U. S. N. (retired); Commander John K. Barton, U. S. N.; Lieutenant Commander Wythe M. Parks, U. S. N.

For Secretary-Treasurer: Lieutenant Commander John R. Edwards, U. S. N.; Lieutenant Commander F. C. Bieg, U. S. N.; Lieutenant U. T. Holmes, U. S. N.; Assistant Engineer R. E. Carney, U. S. N. (retired).

For Council (three to be selected): Commander George W. Baird, U. S. N.; Captain John W. Collins, U. S. R. C. S.; Lieutenant Commander F. J. Schell, U. S. N.; Lieutenant Charles W. Dyson, U. S. N.; Lieutenant Harry George, U. S. N.; Lieutenant C. N. Offley, U. S. N.; Lieutenant D. S. Mahony, U. S. N.; Lieutenant W. R. White, U. S. N.

In addition to the above, the following candidates were also placed in nomination, but withdrew:

For President: Commander Charles W. Rae, U. S. N., and Commander George W. Baird, U. S. N.

For Secretary-Treasurer: Captain Charles R. Roelker, U. S. N., and Lieutenant Charles W. Dyson, U. S. N.

For Council: Lieutenant Commander W. M. Parks, U. S. N., Lieutenant Commander John R. Edwards, U. S. N., Lieutenant R. E. Carney, U. S. N. (Retired), and F. A. Engineer C. N. Green, U. S. R. C. S.

After closing the nominations, the Secretary-Treasurer was authorized to have the ballots for prize essayist of the year prepared in such form as would permit members to express

their opinions upon original articles submitted, as to whether any article submitted during the year is worthy of a prize, in addition to their vote as to the best article. If the vote should be in the negative, no prize will be given.

The Annual Meeting of the Society for the counting of the votes will be held in the Bureau of Steam Engineering, at 2 P. M., Saturday, December 27, 1902.

By order of the Council:

(Signed) C. W. RAE, Comd'r, U. S. N.,
President.

C. W. DYSON, Lieut., U. S. N.,
Secretary-Treasurer.